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R&D FOR FUEL ECONOMY IN AUTOMOTIVE PROPULSION

19 June 1972

A REPORT OF RECORD OF A 15-MEMBER WORKSHOP #8 MEETING HELD ON 16-17 May 1972

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U.S.ARMY TANK-AUTOMOTIVE COMMAND
WARREN, MICHIGAN
USATACOM

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A Report of Record of a 15-Member
Workshop #8 Meeting held on 16-17 May 1972
at
US Army Tank-Automotive Command
Warren, Michigan

Submitted to

The Chairman, Transportation Energy Panel
Sponsored by the Department of Transportation
for
The Office of Science and Technology
by
Chairman of Workshop #8 of TEP

FOREWORD

This report is submitted to the Chairman, Transportation Energy Panel sponsored by the Department of Transportation for the Office of Science and Technology.

Presentations and views on assigned topics and concepts are sorted, discussed, evaluated, ranked, and examined for benefits in energy savings. Candidate concepts with the best energy saving benefit potentials are rated with respect to time and cost. Conclusions are drawn; recommendations are offered.

Wayne S Anderson

WAYNE S. ANDERSON, Chairman
Workshop on R&D for Fuel Economy
in Automotive Propulsion

REPORT BY WORKSHOP #8 ON
R&D FOR FUEL ECONOMY IN AUTOMOTIVE PROPULSION
FOR
THE TRANSPORTATION ENERGY PANEL

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Report of Workshop #8 - TEP

I. INTRODUCTION

A meeting was held on 16-17 May 1972 at Warren, Michigan to examine the subject of R&D for Fuel Economy in Automotive Propulsion in accordance with the charge from the Chairman of the Transportation Energy Panel. Membership of the Workshop is shown on the attached list (Appendix A). The Workshop was conducted as outlined in the attached Letter of Invitation to the members (Appendix B).

In order to (a) summarize the energy challenge, (b) provide reference highway vehicle power-speed maps, and (c) provide a "strawman" set of arguments for initial workshop deliberations and discussions, a set of reference material (dated 12 May 1972), was provided each member at the 16-17 May 1972 meeting. This reference material is attached as Appendix C.

The initial time frame of 0-5 years to affect highway vehicle fuel consumption was adjusted at the opening of the Workshop to encompass an additional increment in the 5-to-10-year time frame. The extension was deliberate, to provide a band of overlap with the subject matter of other workshops within TEP.

II. DISCUSSIONS

A. Topic Sorting

The members presented information and views on their assigned topics as identified in Incl 3 to the Letter of Invitation (Appendix B). The prepared material and references used by members during these discussions is attached (Appendix D), entitled "Working Papers of Workshop #8." Subsequent to the assigned topic discussions, members each presented a topic of their choice, pertinent to the subject. At the conclusion of the presentations and discussions, topics were sorted, some were combined into more generic topics, others eliminated based on a judgment of negligible benefit. The revised list of topics for further examination with an initial estimate of the benefit (energy savings), is given in Table II-1.

Table II-1

List of Topics for Further Examination

		Benefit
1.	Load Factor	10 - 15%
2.	Relief from Planned Emissions Controls	20 - 25%
3.	Liquefied Gas Fuels	-
4.	Small Car	30%
5.	Lean Fuel/Air Engines	20%
6.	Extend Analysis of Highway - Vehicle - Passenger Systems	2 - 7%
7.	Small Base Engine with Boost	15%
8.	Reduce Aerodynamics Drag	5%
9.	Tire Design to Conserve Energy	10%
10.	Fuel - Engine Match	Unknown
11.	Idle Shut-Off	Unknown

Table II - 2

Topics Initially Proposed but Eliminated from Further Direct Consideration in Workshop #8

		Disposition
1.	Dual Engine	Included under "Small Base Engine with Boost."
2.	Accessory Disconnect	Eliminated - Low expected fuel benefit of 1 - 2%.
3.	Town-Country Drive Line	Included under "Load Factor."
4.	Drive-Line Match	Included under "Load Factor."
5.	Utilization of Waste Energy	Included under "Small Base Engine with Boost."
6.	Reduce Base Engine Size	Renamed "Small Base Engine with Boost."
7.	Manual vs Auto Trans	Included under "Load Factor."
8.	EGR & Emission Spark Setting Cut-Out	Included under "Relief from Planned Emissions Controls."
9.	Regenerative Accessory Power	Eliminated - Overall inefficiency of converting energy into storage form and subsequent withdrawal to shaft power.
10.	"Free Tune-Up"	Eliminated - Lack of information. Efforts should be intensified to reduce need for "Tune-Up."
11.	Convert Existing Veh to Liquefied Gas Fuels	Redesignated "Liquefied Gas Fuels."
12.	Public Transportation	Included in "Extend Analysis of Highway - Vehicle - Passenger Sys"
13.	Two-Car Strategy	Included in "Relief from Planned Emissions Controls."
14.	Energy Use Limitation (e.g., tax)	Eliminated since this is Socio-economic Leverage outside Charter of Workshop #8

II. B. Surviving Topic Descriptions or Concepts

1. Load Factor

a. Basic Approach: To operate the engine at its most efficient speed and loading to provide the power demand for the particular vehicle operating condition.

b. Major Components Involved: Engine, transmission, rear axle, and speed-torque ratio control system.

c. Energy Benefit: 10 - 15%

(1) Some experimental results (without full data available on test conditions, duty cycle, etc.) support energy savings as high as 20 - 25%.

(2) A conservative level supported by Workshop #8 as realistically and practically achievable across the entire duty cycle is 10 - 15%.

d. Technology Status: Basic component technology is available. It is essential that the propulsion system design be reoptimized, with subsequent experimental verification.

e. Cost Considerations: Providing a greater ratio coverage, with associated controls, utilizing approaches such as 1 more speed in the transmission or overdrive, etc., is estimated to be an initial cost growth of the order of $100 - $200.

f. Arguments For:

(1) Savings in fuel cost of 15% x $400/yr or $60 per yr appears attractive to consumer. Based on an annual consumption of approximately 1,000 gallons per vehicle at forty cents per gallon including tax. To adjust consumer savings to untaxed portion of fuel cost, multiply savings above by 2/3 or 2/3 x $60 = $40.

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e. Cost Considerations: Providing a greater ratio coverage, with associated controls, utilizing approaches such as 1 more speed in the transmission or overdrive, etc., is estimated to be an initial cost growth of the order of \$100 - \$200.

f. Arguments For:

(1) Savings in fuel cost of 15% x \$400/yr or \$60 per yr appears attractive to consumer. Based on an annual consumption of approximately 1,000 gallons per vehicle at forty cents per gallon including tax. To adjust consumer savings to untaxed portion of fuel cost, multiply savings above by 2/3 or 2/3 x \$60 = \$40.

g. Arguments Against:

(1) Higher initial vehicle cost.

(2) When overdrive systems were offered in the past, their consumer acceptance was minimal.

h. Workshop Working Paper References:

(1) Appendix C-62, 63, 64

(2) Appendix D - Item 3, Page 80
Item 12, Page 111

2. Relief from Planned Emissions Controls

a. Basic Approach: To consider changes in the present vehicle emissions control program, where appropriate to conserve energy.

b. Major Components Involved: Engine and fuel systems with associated auxiliary devices including exhaust gas recirculation (EGR), thermal reactors, catalytic reactors, special fuel air ratio control, spark timing control, and idle speed controls.

c. Energy Benefit: The United States is presently on a course of action to achieve very low automotive emissions from all vehicles, particularly from Model Year 1976 forward. Unfortunately, this monumental effort will result in energy extravagance in at least the early part of the 1977-1987 decade. A major factor contributing to these high fuel penalty solutions has been the tight timetable and the across-the-board approach. It has been contended that a slower, more deliberate approach to emission reduction would allow time for development of alternative solutions with less fuel penalty. This summary description deals with the penalty levels presently indicated.

Energy increase (increased fuel consumption) from Model Year 1968 to Model Year 1976 was selected by this Workshop to be 20 - 25%. This selection of 20 - 25% is consistent with the levels of degradation projected in the National Academy of Sciences report of 1 Jan 72 and the Cumulative Regulatory Effects on The Cost of Automotive Transportation (RECAT) report of 28 Feb 72. RECAT further reports an expectation that improved control measures and new types of engines will enter the market and essentially eliminate the fuel penalty by 1985.

d. Technology Status: EPA has made a recent decision not to extend the implementation date of the 1975 level of emissions requirements. The major automobile manufacturers of this country and foreign suppliers contend that technology is not available to meet the 1975 requirements.

e. Cost Considerations: The two major references, identified in Para c. above, also address estimates of the initial cost increase of automobiles expected in the 1975-76 models as a function of emissions, damage limiting design, and safety requirements. The combined average increase in vehicle acquisition cost is estimated to be $873 to $1,380. Of this increase, $350 - $500 is assigned to emissions controls.

f. Arguments For:

Current strategy to achieve clean air was developed at a time when knowledge and consideration of the effect on energy consumption was limited. Now that the knowledge is improved, reevaluation and adjustment to this strategy should be made with the "energy ethic" in better perspective.

g. Arguments Against:

(1) Such a mid-course change in the utilization of available U.S. resources, including natural resources, technical manpower, facilities and R&D investments would be an extremely ambitious undertaking.

(2) It would require reopening of the issues of "constant air quality," the "2-car strategy," mass transportation, and traffic-flow improvements. Such a master study to achieve the air quality requirement in a manner which will best conserve the limited U.S. energy resources may adjust focus of the major corrective alternatives away from automobile manufacturer control.

h. Workshop Working Paper References:

Appendix D - Item 4, Page 81
Item 5, Page 89
Item 7, Page 101
Item 8, Page 102
Item 11, Page 110

3. Liquefied Gas Fuels

a. Basic Approach: To convert existing gasoline fuel automobiles to permit operation alternatively on compressed natural gas, liquefied natural gas, liquid petroleum gas or gasoline.

b. Major Components Involved: Engine fuel metering devices, on-board storage tanks, and specialized fuel servicing stations.

c. Energy Benefit: An operating experiment by GSA with automobiles demonstrated 9.3 miles per equivalent gallon (based on one hundred cubic ft per gallon) to 9.15 miles per gallon for operation of the vehicles on gasoline. It is noted that this was an operational fleet experiment, all major variables were neither controlled nor measured. Opposite findings are reported in SAE Paper No. 720125 "Evaluation of Gaseous Fuels for Automobiles" presented at 10-14 Jan 72 Automotive Engineering Congress. This paper cites a 16% loss in city fuel economy (on a mile per BTU basis) for a CNG fueled car. In addition to this economy loss, there was a depreciation in acceleration performance of 66%. Further understanding and rationalization of these differences is required prior to the acceptance of any positive energy saving benefit. At this time, the benefit is considered negligible. For valid comparison, further quantification is required with both fuels compared at some future emission level.

d. Technology Status: Technology is available.

e. Cost Considerations: The conversion cost is estimated at about $340 per car in small quantities.

f. Arguments For:

(1) LPG, CNG and LNG have clean burning characteristics with reference to HC & CO, and hence, reduce part of the

exhaust emissions control problem. The NO_x part of the problems continues.

(2) Small fleets of vehicles operating from a centralized service and refueling shop would result in a manageable fuel supply system with minimum capital investment and could result in reduced operating costs.

g. Arguments Against:

(1) Initial cost penalty.

(2) On-board space and weight claim of the compressed gas system.

(3) Lack of readily available refueling points for compressed or liquefied gas.

(4) There is continuing concern that all aspects of the safety issue have not been fully settled. It is recognized that present experimental installations have been certified "safe" but being safe in controlled experiments and being safe in large scale use by the public may involve different dimensions. These existing concerns address such things as:

(a) Denial of access of LG vehicles to tunnels.

(b) Proximity of passengers to high pressure vessels.

(c) Hazard of gas leak from any loss of seal vs gasoline or liquid fuel-leak paths being limited to wetted parts of system.

(d) LG charging stations or stockpiling of recharged tanks at service stations, for example, on three corners of four at major road intersections in urban areas.

(5) Current total demand for gas exceeds U.S. supply. Increase of car use of LG would shift the energy challenge, not contribute to a solution.

h. Workshop Working Paper References:

Appendix D - Item 10, Page 104

4. <u>Small Car</u>

a. Basic Approach: To encourage and emphasize the present trend from standard cars to small cars. Of the 87 million passenger cars in use during base year 1969, 7.7 million were small vs 79.1 million standard and compact. Annual sales of the small cars have been increasing dramatically, approaching 25% of total car sales in 1971. In base year 1969, the small car density of 8.9% traveled 8.9% of the miles and consumed 5.5% of the fuel. Average small car fuel economy is 22.0 miles per gallon, compared to 13.14 miles per gallon for standard cars. Fuel savings is, therefore, about 3.4%.

b. Major Components Involved: All; actually the result is based on a combination of scaling effects, predominately weight of 4,000 to 2,000 lbs and size (frontal area $\longrightarrow$ ½ of standard).

c. Energy Benefit: The energy advantage of weight and size supports the expectation of substantial savings (30%) with no trade-off of driveability. Some connotations of "small car" accept moderate to severe reductions in driveability. In such special cases, the energy savings expectation is greater, but marketability is believed to be less. Additional savings are expected if performance (e.g. acceleration) is sacrificed.

d. Technology Status: The "small car" is available in the marketplace today.

e. Cost Considerations: The initial or acquisition cost of the small car to the consumer is a substantial advantage. For comparison, the standard car is assumed at a consumer price of $3,500 to $4,000 as compared to the small car at a consumer price of $2,400 to $2,800. The operating fuel cost advantage to the consumer is also substantial at 35% x $400 per year, or $140 per year. $140 saving includes tax. Savings on fuel cost not taxed is 2/3 x $140 or $93.

f. Arguments For:

Savings in both acquisition cost and the operating fuel cost are substantial and believed to be the basic motivation in the consumer trend to buy more small cars.

g. Arguments Against:

(1) The small car is less safe, particularly in collision with heavier vehicles.

(2) Less comfortable.

(3) Low carrying capacity--is small and cannot meet varying demands of larger family sizes for special purposes, such as vacation trips. (This could be offset by increasing availability and promoting use of rental "vacation vehicles.")

(4) Less attractive for the single-car family, but attractive for the multiple-car family.

h. Workshop Working Paper References:

Appendix C-60, 62, 65

Appendix D - Item 11, Page 110

5. Lean Fuel/Air Engines

a. Basic Approach: This term as discussed in this Workshop applies to the broadest definition associated with piston engine types. It includes the diesel and stratified charge engine concepts. The similarities of the combustion are initiation of flame in a restricted fuel-rich zone with excess air surrounding the rich zone, with control of flame front propagation to rapidly crossover from the rich region to the lean region with minimum time at stoichiometric. Other elements of commonality between the classical diesel and the newer stratified charge include precise fuel metering by use of high to moderate pressure injection systems and unthrottled air delivery with improved inter-cylinder distribution and intra-cylinder control of "swirl" in the combustion chamber.

b. Major Components Involved: From the vehicle viewpoint, this approach involves primarily the engine assembly. There will be interfacing trade-offs, including weight and space claim considerations, and also presenting a different engine fuel consumption island map which will change the details of the drive-line matching compromises.

c. Energy Benefit: 20%

The stratified charge engine offers a higher energy benefit under part-load, part-speed conditions. This advantage decreases as load and speed increase. The diesel engine offers a more uniform advantage, less dependent on speed and load variations. For subsequent consideration, 20% energy benefit is assigned as a nominal across-the-board advantage.

d. Technology Status: Diesel engine technology is well advanced. Further optimization is required to reduce weight, to trade-off lower emissions of prechamber with the energy conservation of the open chamber, and to provide aggressive efforts to simplify fuel injection systems leading to lower cost at higher production rates. Stratified charge engine technology is on the verge of completion of substantial exploratory development. Expansion to full scale, advanced development at the earliest time is essential. Like the Diesel, a concerted effort to simplify the fuel injection system is important. No fundamental technological voids or obstacles are identified at this time. However, advanced development with feedback for correction and engineering refinement is in order.

e. Cost Considerations: Carbureted engines in sizes from 75-to-250-horsepower can be manufactured competitively at $3 to $5 per horsepower. For this same range of powers, fuel injection systems will increase that basic cost by $1 to $2 per horsepower. In other words, this class of lean fuel/air engines as compared to conventional spark ignition engines is expected to have an increased cost of $150 to $400.

f. Arguments For:

(1) Precise control of fuel and air distribution, and type of combustion offer the most energy conservative solutions for reduction of harmful exhaust emissions products.

(2) Energy conservation of not less than 20% is substantial. If a hypothetical car engine were at the 200-horsepower size, the acquisition cost penalty is expected to be about $400 to the consumer. At an operating cost savings of 20% x $400 or $80 per year, this includes fuel tax; the breakeven point would be at five years operation.

(3) A reduction of the acquisition cost premium is envisioned as a result of increasing competition in design and manufacture of fuel injection systems at annual rates approaching one million units compared to present rates of one hundred thousand units.

(4) The effect of feeding back the energy savings into a constant air quality target could be determined. With emissions accurately quantified, then there will be a basis to further consider simplification of chemical treatment systems, now envisioned for standard engines. If simplification is supportable, the resulting installed vehicle power system could provide reduced maintenance time and cost to consumer.

g. Arguments Against:

(1) The premium and initial cost of engine, and in turn to the vehicle consumer, is high ($150 to $400, depending on size). This level of increased cost is likely to be unacceptable to the consumer if he is going to be exposed to the acquisition cost increases projected from emissions, damage limiting design and safety requirements of $873 to $1,383.

(2) The engine will be more complex than the simple carbureted gasoline engine. The stratified charge engine will incorporate a fuel injection system in lieu of carburetion but in addition to the spark ignition system. The Diesel engine will include a higher pressure fuel injection system but not a full-time high energy ignition system. It may require "glow plugs" to enhance cold startability for car service. Not only does this additional injection system increase costs, but it also increases complexity of the base engine. Further effort will be continued to be required to simplify the fuel injection system. This is recognized as a substantial engineering problem and not a technological obstacle.

(3) Production capacity within the U.S. for high pressure injection systems is limited. A ten-to-hundredfold increase in this capacity is considered to be a substantial undertaking even though there are no major technological barriers.

(4) Advanced developments of the stratified charge engine and engineering refinements of both stratified charge and Diesel engines for passenger cars are expected to require a period of time in the order of five years. Hence, the expectancy for production readiness is in the time frame of five-to-ten years forward.

(5) Diesel engines produce odors which are marginal in certain vehicles, e.g., city buses. (Programs aimed at increasing the use of Diesel engines in congested areas should carefully examine the potential aggregate odor problem and provide assurance that the odor level is acceptable.)

h. Workshop Working Paper References:

None.

6. Extend Analysis of Highway - Vehicle - Passenger Systems

a. Basic Approach: To continue existing efforts to improve utilization of existing cars, e.g., passenger loading of 2.2 passenger/vehicle, to improve traffic flow on existing roads, utilization of existing roads, and to encourage use of public transportation with reserved bus lanes and improved mass transit systems.

Some of these past and continuing efforts have optimized time and safety. Solution alternatives have not yet fully considered the goal of energy conservation. Hence, results should be reviewed and assigned energy conservation rankings. Available models should be re-exercised toward minimum energy demand solutions. A new set of time-energy balanced solution alternatives should be established.

b. Major Components Involved: This effort concentrates on people, optimizations of road use, modal or submodal shifts of transportation demand, and does not deal directly with technology of the dominant highway vehicles, cars and trucks.

c. Energy Benefit: 2% - 7%

(1) An example of expected benefit of improved traffic flow in a to-and-from-work, one-way trip of 9.4 miles supports energy savings potential of 32 to 36%. This first example is toward the lower end of expected benefits.

(2) Toward the higher end of the spectrum is the order of magnitude energy savings anticipated from mass transit. For example, a shift of 50 passengers from 25 cars to one 50-passenger bus operating in reserved lanes could result in a ratio of fuel consumption of

7.2:1 (approximately one order of magnitude) in favor of the bus, or a savings of $\frac{6.2}{7.2}$ x 100 = 86%.

(3) Both of these examples are simplified and offered as representative of the many possible solutions under consideration. However, such simplified examples should be properly qualified to retain perspective.

(4) The example of improved traffic flow for the car on a 10-mile, one-way trip offers a fuel savings of about 35%. But this would be realized where traffic is congested at speeds of the order of less than 15 mph with frequent stops. Of the total car miles traveled, 60% is in communities of more than 50,000 population. In urban areas, 80% of the cars on primary roads and 50% of the cars on secondary roads travel at speeds greater than 35 mph. Although data is not readily available to identify the car miles in a congested traffic situation as described in the example, it is assumed to be about 20% of total car miles. Therefore, annual energy savings could be 20% x 35% or 7%.

(5) On the other hand, the bus operating on exclusive lanes, example is more severely adjusted for different reasons. Some major factors are that it would become economically feasible in larger cities, that density of residences should be high, and perhaps most importantly that there is uncertainty on public acceptance and use. Starting with the data that 10% of passenger car miles are traveled in cities of more than one million population and assuming that 25% of car travel would shift to bus, the adjusted annual energy savings would be 85% x 10% x 25% or about 2%.

d. Technology Status: Not applicable.

e. Cost Considerations: Not available to this group, Workshop #8.

f. Arguments For:

(1) Very high expected energy benefit on congested roads, extending from one example of about 35% to a simple shift to mass transit with benefit of about 85% which approaches one order of magnitude improvement.

(2) More comprehensive arguments both for and against should be identified by qualified transportation systems experts.

g. Arguments Against:

(1) None obvious to Workshop #8 for improved traffic flow.

(2) Uncertainty of public acceptance is a primary concern for "mass transit" as illustrated by the bus on exclusive lane example.

h. Workshop Working Paper References:

(1) Appendix C-62, 63, 65

(2) Appendix D - Item 6, Page 93
Item 7, Page 101
Item 8, Page 102
Item 9, Page 103

7. Small Base Engine with Boost

a. Basic Approach: Substitute smaller engine, e.g., 6-Cyl for 8-Cyl and provide continuous boost device, such as a turbocharger to provide same power. Fundamental car or truck performance, acceleration and passing maneuvers, in particular, would remain constant. The smaller, lighter base engine provides power demand expected for some 75 to 90% of the time. Such a smaller engine starts easier, warms up quicker, has less absolute friction losses because of size, and less relative friction losses because it operates more at higher load factors.

b. Major Components Involved: Engines with supplemental boost power. In this concept the boost devices are limited to increasing of charge densities and include turbochargers and superchargers with or without gas bypass or hydraulic or pneumatic "starters." Excluded is the electric boost commonly called "heat engine - electric hybrid."

c. Energy Benefit: 15%

This approach provides a substantial advantage below ½ power demand. Hence, the conservative driver (moderate accelerations and modest top speeds of the order of 60 mph) would expect full advantage of 20+%. At full power demands, this concept could vary from a standoff to a slight loss up to 5%. As a conservative across-the-board saving, this group supports 15%.

d. Technology Status: Basic technology is available. Effort should be focused on stimulation of turbocharger suppliers to simplify designs to passenger car levels of driveability and annual production rates. Such efforts are expected to result in substantial reduction in small turbocharger costs. A concerted engineering effort is required to match turbochargers to specific engines.

Reduction in engine compression ratio is expected to avoid need for fuel with higher octane number. Basic engines of 4 and 6 cylinders are in full production, and are available within car and truck companies for optimization with turbo's to substitute for higher displacement 6's or V-8's.

e. Cost Considerations: The major engine cost increase is caused by the addition of the turbocharger and associated manifold and possibly special controls. Small (3" wheels)turbochargers are currently being manufactured and sold at less than $75 for smaller diesel engines. A 10-to-100 times annual production rate is expected to provide a price reduction. Coupled with some savings in basic 6-Cyl engine cost vs 8-Cyl engine, the net cost increase of the 6-Cyl engine with turbocharger boost is expected to be under $100.

f. Arguments For:

(1) Annual fuel savings of 15% x $400 = $60 (including tax), = $40 (excluding tax), could offset acquisition cost premium of about $100 in less than two years.

(2) Car performance would be constant at consumer demand level of 1970.

(3) Operating cost savings would continue for life of vehicle.

(4) Fringe benefits of easier starting, and quicker warm-up are favorable.

g. Arguments Against:

(1) Acquisition cost to consumer is higher of the order of $100.

(2) Engine with turbocharger is more complex than without.

(3) Abuse of car by extended operations at high power could lead to shorter life of engine.

(4) Either boosted octane requirement is increased or part load economy is compromised by reduced compression ratio.

(5) There will be some lag in acceleration and therefore, some loss in transient performance unless technology for a turbo "kicker" can be developed.

h. Workshop Working Paper References:

(1) Appendix C-62, 63, 65

(2) Appendix D - Item 13, Page 118

8. <u>Reduce Aerodynamics Drag</u>

a. Basic Approach: To improve shape to reduce aerodynamic drag. Energy savings vary linearly with drag coefficient and frontal area and with cube of speed. This approach accepts speed trends as they are and does not envision energy savings regulation of speed.

b. Major Components Involved: Exterior surface shapes including car bodies, truck cabs and bodies, tractor cabs and semitrailer bodies and bottoms or undercarriages of cars and trucks.

c. Energy Benefit: 5%

(1) Depending on specific vehicle weight, size and shape, the power required to overcome air resistance is equal to the power required to overcome level road rolling resistance in the broad range of 35-60 mph. The lower speed is for the car and higher is for larger trucks. Drag coefficients for this spectrum of cars through tractor-trailers are from 0.00125 for 4-door sedans to 0.0025 lbs/ft^2 $(mph)^2$ for trucks. A streamlined body of revolution has $D_C = 0.000075$ lbs/ft^2 $(mph)^2$ as compared to a flat square plate with $D_C = .00326$ lbs/ft^2 $(mph)^2$. Noting that the experimental data on trucks is .0025 which approaches the flat square plate of .0036 vs the teardrop of .000075, the potential for improvement is a factor of $\frac{.0025}{.000075} = 33:1$.

(2) If an improvement of D_C of 2:1 could be achieved, this would reduce air horsepower at about 50 mph to ½. This would translate into a 25% energy benefit at steady state 50 mph level road operation.

(3) Refocusing design attention to this energy payoff source is expected to result in at least a 5% energy pay-off in the real duty cycle for all cars and trucks.

d. Technology Status: Basic technology is available. This effort is expected to require engineering trade-offs of front corner radius on tractor cabs and semitrailers vs cab interior space and [illegible], vs manufacturing process and cost. Re-examinations of "belly pan" on cars, etc., are also envisioned. Styling could be a more formidable obstacle than engineering.

e. Cost Considerations: Unknown at this time. First order benefit is expected at minimal or negligible cost to consumer. Some moderate R&D and engineering program costs would be expected.

f. Arguments For:

(1) Potential energy savings for higher speed operation (75-80 mph) is very high and could exceed 50%.

(2) Modest improvements at negligible cost are expected to provide 5% energy benefit for all new cars and trucks operating on normal duty cycles.

(3) Available technology may have been set aside inadvertently.

(4) Some energy gain could be expected as an extension of on-going noise control and highway safety programs.

(5) Reduction of "bow wave" effect of truck-car passing would improve highway safety.

g. Arguments Against:

(1) Program costs and manpower and facility resources may be in short supply and in competition with other work assigned higher priority.

(2) Shape optimization could detract from individual styling.

(3) Aerodynamic shapes generally reduce volume of a given overall length so that either interior space may have to be sacrificed or exterior length may have to be increased. (Unfortunately this may be particularly true with small cars.)

h. Workshop Working Paper References:

(1) Appendix C-62, 63, 65

(2) Appendix D - Item 6, Page 93
Item 9, Page 103

9. Tire Design to Conserve Energy

a. Basic Approach: Replace bias ply tires with radial ply tires at time of tire replacement on in-service vehicles, and on vehicles during new production.

b. Major Components Involved: Tires primarily with interfacing verification of vehicle stability as function of suspension systems compatibility.

c. Energy Benefit: 10%

(1) For vehicles operating at modest to low speeds generally under 50 mph when rolling resistance is substantial or dominant portion of power demand, the potential benefit is about 25%. This advantage diminishes at higher speeds as air resistance becomes dominant power demand. Experimental test results, both controlled and uncontrolled, (operational experiences), support fuel savings varying from 5 - 7% to 28%.

(2) With a degree of intuitive judgment, this group supports an expectation of overall energy benefit of 10%. This is particularly attractive because such a change could be introduced to all in-service vehicles at time of normal tire replacement or all vehicles could be "retired" in about two years.

d. Technology Status: Tire design technology is understood to be available. The technical issue is to verify compatibility with suspension systems and fully assess some reports of poor handling and ride harshness compromises. There is a continuing uncertainty of adverse handling resulting from the incompatibility of mixing radial and bias tires on a vehicle. This doubt applies particularly to the older in-service vehicles. The pacing issue appears to be how rapidly the U.S. Tire Industries can changeover to the different manufacturing processes for radial tires.

e. Cost Considerations: Initial cost of the radial tire is higher than bias tire. The approximate increase is 30 - 50% with limited U.S. production base. However, the tread-life advantage is supported by experimental data to be 70 - 100%. Hence, tire life cycle (2 - 3 yrs) cost is less.

f. Arguments For:

(1) Energy savings of at least 10%.

(2) Increased tread life 70 - 100%.

(3) Increased traction on wet and snow covered roads.

(4) Puncture resistance.

(5) Increased mobility off road.

g. Arguments Against:

(1) Potential incompatibility with existing suspension systems.

(2) Initial cost is greater by 30 - 50%.

(3) Limited production base.

(4) Logistics problems during transition, e.g., disposal of bias tire inventories, compatible wheel locations for mixed sets of tires, etc.

h. Workshop Working Paper References:

(1) Appendix C-62, 63, 65

(2) Appendix D - Item 6, Page 93
Item 9, Page 103
Item 14, Page 120

10. Fuel-Engine Match

a. Basic Approach: To stimulate and encourage increased emphasis of fuel-engine compatibility experts, such as the Coordinating Research Council (CRC), to provide qualitative and quantitative standards to measure fuel cleanliness factors which result in dirty engines after combustion. These deposits are those remaining within the engine structure in gum, varnish, and more complex forms. In general, such "dirt" adversely affects engine performance and durability. Secondly, these expert groups should be charged with more extensive studies to fully describe and specify fuel characteristics which will enhance more precise fuel delivery to individual cylinders, utilizing carburetion or injection pump systems.

b. Major Components Involved: Fuel-engine compatibility.

c. Energy Benefit: Unknown

Fuel with improved physical characteristics to enhance uniform charge distribution could contribute to elimination of present design practice of nominal over-rich charges to avoid lean misfire due to variability in delivery to individual cylinders. "Cleanliness" is expected to assume even more significance as more devices are added for emissions controls. It could well become a substantial factor in the 50,000-mile durability requirement.

d. Technology Status: Unknown by this group but expected to be reasonably in hand by "fuel-engine" experts.

e. Cost Considerations: Unknown

f. Arguments For: Defer to fuel experts.

g. Arguments Against: Defer to fuel experts.

h. Workshop Working Paper References:

None

11. Idle Shut-Off

a. Basic Approach: Limited information was available to the group which identified a technique to shut engine off when foot was taken off of the gas pedal and to automatically restart when foot was reapplied to the gas pedal. The approach is simply to look into this technique for preliminary assessment.

b. This topic is considered novel and speculative rather than a growth investment like the preceding ten topics. As a starting point for a preliminary search, the device or technique is believed to have originated in Japan and is applied in the U.S. to gasoline-powered golf carts.

c. Energy Benefit: Unknown

II. C. Surviving Topic Categorization and Ranking

First - attention is devoted to separation of the eleven topics into two groups: one which is applicable to vehicles now in service (100×10^6); and the other, to changes that are most likely to be introduced in new manufacture or at a rate of some 10×10^6 per year. This means that in Tables II-5, II-8, and subsequent discussions involving energy benefit forecasts, the percentages shown apply to each new vehicle as produced. Hence, with reference to the energy savings across the whole 100×10^6 vehicle operating fleet, fuel savings will accrue at 1/10 of the percentages indicated per year.

Table II - 3

Topics by Categories based on Application

A. Immediate Application	B. Effective in New Production
1. Tire Design (U.S. Production Capacity Increase is Required)	1. Load Factor
2. Liquefied Gas Fuel	2. Relief from Planned Emissions Controls
3. Systems Studies	3. Small Car
	4. Lean Fuel/Air Engine
	5. Small Base Engine with Boost
	6. Reduced Aero Drag
	7. Fuel-Engine Match - Further Study Required
	8. Idle Shut-Off - Further Study Required

Next, each of these categories is ranked in order of energy benefit potential.

Table II - 4

Ranked List of A ("Now") Category

		Energy Benefit
1.	Tires	10%
2.	Systems Studies *	2 - 7%
3.	Liquefied Gas Fuels	Negligible **

Notes: * Some concepts can be introduced **now**, others are longer range.

** This is a provisional benefit assignment. It is subject to verification.

Table II - 5

Ranked List of B ("Later") Category

		Energy Benefit
1.	Small Car	30%
2.	Relief from Planned Emissions Controls	20 - 25%
3.	Lean Fuel/Air Engine	20%
4.	Small Base Eng w/Boost	15%
5.	Load Factor	10 - 15%
6.	Aerodynamic Drag	5%

With particular emphasis to production readiness of the six topics for future production, time judgments are as follows:

Table II - 6

Production Readiness Expectation of Ranked B ("Later") Category

		0 - 5 Yrs	5 - 10 Yrs
1.	Small Car	Yes	Yes
2.	Relief from Planned Emissions Controls	Yes	Yes
3.	Lean Fuel/Air Engine	No	Yes
4.	Small Base Engine	Yes	Yes
5.	Load Factor	Yes	Yes
6.	Aerodynamic Drag	Yes	Yes

Although very little information was available to the members on cost for changes not yet completely defined, there is a basis for judgments in levels of cost and whether or not they will be more or less to the consumer. Low is loosely defined as up to \$100 - \$200, and high is defined for about \$300 - \$500$^+$ level.

Table II - 7

Changes of Initial Cost to Consumer

	More		Less	
	High	Low	High	Low
1. Small Car			X	
2. Partial Relief for Planned Emissions Controls			X	
3. Lean Fuel/Air Engine	X			
4. Small Base Engine		X		
5. Load Factor		X		
6. Aerodynamic Drag	(Negligible)			

An adjusted ranking of "later" concepts listed in Table II - 5 with preliminary consideration of time shown in Table II - 6 and cost in Table II - 7 is as follows:

Table II - 8

Adjusted Ranking Based on Elemental Cost - Benefit Consideration

		Energy Benefit
1.	Small Car	30%
2.	Relief from Planned Emissions Controls	20 - 25%
3.	Load Factor	10 - 15%
4.	Small Base Engine w/Boost	15%
5.	Lean Fuel/Air Engine	20%
6.	Aerodynamic Drag	5%

Primarily cost, but to some extent time of production readiness were considerations in displacing Lean Fuel/Air Engine from 3 to 5 position. Also simplicity and earlier availability, and absence of fuel octane increase considerations were reasons for Load Factor to precede Small Base Engine in final ranking.

II. D. Combining Potential of Individual Concepts

1. A preliminary subjective look at combining potential is believed to be within reason for this workshop. It is recognized and acknowledged that this is a comprehensive subject which should have benefit of intensive analysis. Features which reduce power requirements such as low resistance tires, small cars and aerodynamics drag are generally additive; but features which are designed to reduce the brake specific fuel consumption of the engine, such as load factor, small engine with boost, and lean F/A engine are not additive because they "bump against" the basic thermodynamic efficiency limits of the engine cycle.

2. Starting with the obvious, improved (low energy consumption) tires reduce the power demand for a given transportation action and would therefore be additive to a large extent to all other changes. It may cause the engine to operate at a lower (less efficient) load factor at a given speed. This would tend to increase the pay-off of load factor optimization. On the other hand, the reduced rolling resistance on the tire will tend to shift a higher work load to the vehicle brake system.

3. Perhaps the least additive are Lean Fuel/Air Engines and Load Factor. The Lean Fuel/Air Engine is better than the standard gasoline engine, in particular, at partial loads and moderate to low speeds. Hence, some of the advantage of Power Train optimization is achieved thermodynamically within the Lean Fuel/Air Engine. This changes the speed/torque potential available for mechanical optimization of transmission and axle ratios. These two concepts are a strong example of interaction and interdependency of a subsystem--the power train.

4. The Small Base Engine with Boost is a special way to force most low power demand operations at a favorable load factor. It offers additional potential for quicker warm-up, lower frictional losses, and attendant weight and space claim advantages.

5. In a short workshop, there is no apparent meaningful way to quantify additive potential of the changes. The best we can offer is a consensus opinion based on judgments of the group. Such a judgment for the combined energy benefit potential expected from optimization of Tire Design, Aerodynamic Drag, and Lean Fuel/Air Engine (or Load Factor or Small Base Engine w/Boost) is 30%.

6. Such a 30% reduction on fuel consumed would substantially reduce the total products of combustion. Although the profile of harmful emissions content of the reduced combustion products is unknown, it could be favorable. Emissions at this reduced fuel level should be determined to allow further consideration of alternatives to achieve air quality goals with minimized use of energy.

III. CONCLUSIONS

A. Based on background and reference information provided, Workshop #8 accepted the following as given conditions:

1. Low cost petroleum natural resources are declining in the United States. Price of fuel is expected to increase with the dwindling low cost U.S. natural sources. The price ratio some time in the future, e.g., 1985 compared to today is not known. Some synthetic alternatives are projected at 1.5 x today's price.

2. Petroleum fuel, natural or synthetic, can be produced to meet transportation demands in the U.S. for some extended time. There is little doubt that petroleum can be the dominant fuel through at least 1985.

B. With this frame of reference, the deliberations in Workshop #8 resulted in the following conclusions:

1. Technology is available to apply to the car and truck to save energy in the future.

2. A realistic cumulative potential energy savings is 30%.

3. Preoccupation with achievement of regulatory requirements, in particular, the 1976 levels of emissions controls are heading for energy extravagant solutions with fuel penalty of 20 - 25%.

4. Technology is available to offset this 20 - 25% penalty by application of resources toward production readiness of the energy savings technologies. Energy consumption could be held status quo even though emissions cost would be 20 - 25%.

5. Energy conservative changes will result in higher initial cost to consumer even though life costs most likely will be less.

6. Faced with the cumulative regulatory effect on initial cost by emissions control, damage limiting design, and safety, the consumer is not likely to be receptive to additional cost for energy conservation.

7. Although "free enterprise" application of energy saving changes is considered best, it is unlikely to happen in the current economic environment.

8. Motivation (consumer pressure) is the key to rapid progress to achieve energy conservative measures for which technology is available.

9. Means to activate energy conservative measures should be addressed encompassing the whole spectrum of alternatives including socioeconomic, regulatory, legislative as well as the limited consideration of technological leverage.

10. In any event the largest contribution to save fuel in the earliest time frame would be the introduction of a tire with reduced rolling resistance which, in turn, could lead conservatively to a 10% reduction of fuel consumed.

IV. RECOMMENDATIONS

Therefore it is recommended that:

1. Available tire design information and experimental data be re-examined to verify the expected reduction in fuel consumption of at least 10%. That a knowledgeable study group, involving at least Government, and Car, Truck and Tire Industries be assembled to address means to accelerate availability of such improved tires. Compatibility of mixed tire sets on existing vehicles should be verified concurrently by examination of available data and/or conduct of new experiments as "vehicle-tire" experts may determine.

2. Factual information be made available to the consumer through various educational media concerning conservation of energy and individual consumer operating expenses for cars and trucks which could be expected from alternatives such as those discussed in this report.

3. Government agencies and automotive and truck companies re-optimize their vehicle design alternatives and identify energy conservative vehicle which could be made available to respond to the expected consumer demand. (Consumer demand is expected to be triggered by increasing cost of energy.)

4. The proper Government agencies examine regulatory or taxation alternatives on energy use to accelerate an earlier stabilization of the energy market.

5. Middle time frame highway vehicle planning use the assumption that natural or synthetic petroleum will be the abundant fuel through about 1985.

6. Fuel cost growth expectation by 1985 be assumed at 2.0 x 1970 cost to accelerate earlier stabilization of the energy consumption in highway vehicles.

7. The Government sponsor an R&D Program to identify more clearly engine concepts for highway vehicles with a tolerance to operate on the promising alternate fuels being addressed by the energy industries. (Such a basic study would provide centralized visibility and insight to improve structure of longer range engine R&D plans and programs to optimize utilization of limited dollar and talent resources.)

11 May 1972

TRANSPORTATION ENERGY PANEL

Workshop #8 - R&D for Fuel Economy in Automotive Propulsion

Membership

	Name	Organization Source	Phone
1.	W. S. Anderson	TACOM	(313) 573-2411
2.	G. J. Huebner (J. P. Francischina, Alternate)	Chrysler	(313) 956-3534
3.	W. M. Brehob	Ford	(313) 323-4095
4.	C. Marks	General Motors	(313) 575-1131
5.	W. A. Wallace	EMA	(312) 378-4100
6.	J. T. Gray	SWRI	(512) 684-5111
7.	P. S. Myers	Univ of Wis	(608) 263-1615
8.	A. Frank	Univ of Wis	
9.	N. H. Beachley	Univ of Wis	(608) 262-3594
10.	E. N. Petrick	TACOM	(313) 573-1142
11.	K. Hellman	EPA	(313) 761-5230
12.	C. F. Izzard	DOT/FHA	(202) 426-0255
13.	W. B. Foote	GSA	(202) 254-5374
14.	R. A. Dockus	GSA	(202) 254-5340
15.	R. A. Husted	DOT	(202) 426-2900

Appendix A

AMSTA-RG

1 MAY 1972

One of the major tasks facing the R&D community during the next few decades is to assure the availability of an abundant supply of energy. The Federal Council for Science and Technology has established an Energy R&D Goals Committee to follow on the President's Energy Message of June 4, 1971. Panels in eleven different technology areas are being sponsored by cognizant agencies. These cover all aspects of energy generation, transmission, storage and utilization.

The Department of Transportation sponsored effort is identified as the Transportation Energy Panel. The purpose of this letter is to request your support in the workshop substructure of this panel.

On behalf of the Transportation Energy Panel Chairman, an invitation is extended for a Representative of your office to participate as a member of one of eight workshops to be conducted during May 1972. This workshop is to address Research and Development for Fuel Economy in Automotive Propulsion.

Appendix B

AMSTA-RG

1 MAY 1972

I have the assignment as a member of the TEP, to organize, chair and report the findings and consensus technical judgments of the workshop back to the Transportation Energy Panel.

The theme of this Fuel Economy Workshop is to identify, examine and rank technological alternatives to conserve consumption of petroleum fuel in particular in the near time frame of 0-5 years.

This workshop will meet in Warren, Michigan on 16 & 17 May 1972. Details of place and time are included in the attached draft Agenda.

Petroleum is one of our major sources of energy and accounts for virtually all of the energy used in transportation. Conversely, 53% to 63% of our petroleum is used in transportation. Within transportation, automobiles consume some 52% of this energy. Hence, the dominant transportation vehicle consumer is the automobile and short term conservation alternatives should focus attention to the auto.

Recognizing limitations of shortage of lead time for this workshop, enclosed are drafts of tentative membership, Workshop Agenda, List of Topics, and Guidelines for Workshop Members. Your early consideration of this invitation would be appreciated.

Please phone your acceptance or the name of your representative to me at 313/573-2411 or 313/573-2413. Also please pass the information in this letter to your representative to allow maximum available time for preparation for the Workshop on 16 & 17 May 1972.

1 MAY 1972

AMSTA-RG

I wish to emphasize my personal conviction of the urgency of this matter, and sincerely hope you will be able to share the knowledge and experience of your offices with the workshop members so that we can make a constructive input to the Transportation Energy Panel.

Sincerely yours,

Ltr sent 11 May 72

WAYNE S. ANDERSON
DOD Representative to
Transportation Energy Panel

4 Incl
1. Proposed Members
2. Agenda
3. List of Topics
4. Guidelines for Workshop

DRAFT
28 Apr 72
WSA

TRANSPORTATION ENERGY PANEL

Workshop #8 - R&D Fuel Economy in Automotive Propulsion

	Initial List of Topics for Examination	Assignment of Proponency for Workshop Discussions
1.	Dual Engine - e.g., 4-Cyl for Town and 8-Cyl for Country.	Chrysler Rep
2.	Accessory Disconnect - e.g., Fan, AC, Power Steer, Generator.	Ford Rep
3.	Town-Country - e.g., 2-speed Rear-Axle or Splitter behind Transmission.	General Motors Rep
4.	Drive-line Match - Base Design 0-60 MPH with Stretch Gear (OD) for 70-85 MPH.	EMA Rep
5.	Utilization of Waste Energy from Thermal Reactor.	SWRI Rep
6.	Reduce Base Engine Size - Offer Modular Power Boost Devices such as Super-charger, hydraulic or electric accumulators, etc.	Univ of Wisconsin Rep
7.	Manual vs Auto Transmission - Optimize best fuel map from engine with least drive-line loss.	Wayne State University Rep
8.	EGR and Emission Spark Setting Cut-Out - Scheduled excursions reference to power demand or throttle position.	TACOM Rep
9.	Regenerative Accessory Power - Energize loads like "generator" during deceleration only.	EPA Rep

Initial List of Topics for Examination	Assignment of Proponency for Workshop Discussions
10. "Free Tune-Up" - Adjustment and parts replacement advice.	FHA Rep
11. Convert Existing Vehicles to Liquefied Gas Fuels.	GSA Rep

DRAFT
28 Apr 72
WSA

TRANSPORTATION ENERGY PANEL

Workshop #8 -- R&D for Fuel Economy in Automotive Propulsion

Guidelines for Conduct of Workshop

1. Each member will prepare two topics for presentation to and discussion with the group. The first topic is by arbitrary assignment identified on Initial List of Topics Draft by WSA dtd 28 Apr 72. The second topic is to be a choice of the member.

2. Prepared information will include embellishment of the given and chosen topic thoughts into a concept outline. Additional available information and judgments should follow outline in the enclosed Agenda. Items 6 & 10 in this outline should be left blank for completion by the whole working group.

3. Prepared information will be brought to the Workshop Meeting in 15 copies for distribution to all members for reference and continuing work sheets during the meeting.

4. Each member will present oral summation of the topic concept and significant pros and cons. This informal presentation is expected to be given in 10 to 15 minutes per topic.

5. Target for end of first day of Workshop is to boil-up a preliminary gross ranking the ten best concepts from 11 assigned plus at least 11 chosen concepts.

6. The second day of the Workshop will extend examination of the ten best concepts via discussion and elementary benefit--cost consideration.

7. Target for end of second day is to identify program alternatives to pursue the top five of the top ten list of concepts.

8. Contributions to this Workshop are dependent on the knowledge, expertise and innovation of the individual members. Use of Organizational or Company references are for convenience of identification only.

1 Incl
Outline

WAYNE S. ANDERSON
Chairman, Workshop #8

AGENDA

(FOR INDIVIDUAL CONCEPTS WITHIN EACH SUBTECHNOLOGY)

1. Concept Outline
2. Objective (transportation point of view)
3. Present Status
   a. Maturity (by reference to objective)
   b. Support Level:

      National (Federal and Private)

      International
   c. Contributors

      National (Federal and Private)

      International
4. Outline of Problems
5. Recommended Action (for reaching technological readiness)
   a. Funding levels
   b. Timetable
   c. R&D teams
6. Rank (within subtechnology by comparison to competing concepts)
7. Estimated Effort, Schedule and Cost to reach commercial readiness, (qualification)
8. Impact on Resources
9. Environmental and Ecological Impact
10. Conclusions and Recommendations

Incl to Guidelines for Conduct of Workshop #8

WORKSHOP #8

TRANSPORTATION ENERGY PANEL

REFERENCE MATERIAL

(APPENDIX C)

(For use during Meetings, 16 & 17 May 1972
at TACOM, Warren, Michigan)

Prepared by:
Wayne S. Anderson
Chairman, WS #8
12 May 1972

Reference Material

APPENDIX C

Contents

11 May 1972

TRANSPORTATION ENERGY PANEL

Workshop #8 - R&D for Fuel Economy in Automotive Propulsion

Membership

	Name	Organization Source	Phone
1.	W. S. Anderson	TACOM	(313) 573-2411
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14.	R. A. Dockus	GSA	(202) 254-5340
15.	R. A. Husted	DOT	(202) 426-2900

11 May 1972

TRANSPORTATION ENERGY PANEL

Workshop #8 - R&D for Fuel Economy in Automotive Propulsion

AGENDA

Meeting to be held in Conference Room A1052 of Bldg #200A, TACOM, Warren, Michigan. (Enter Mound Road Gate between 11 & 12 Mile Roads to Engineering Lobby, Bldg 200A.)

Tuesday, 16 May 1972

0900 - Introduction and Workshop Goal Review

0930 - Member Presentation of Arguments of Assigned Concepts

(1030 Coffee)

1200 - Lunch

1300 - Member Presentations of Concepts of their Choice

(1430 Coffee)

1500 - Consensus Ranking of most Sensible Concepts for Concentration of Benefit/Cost Consideration on Wednesday, 17 May 1972

1600 Adjourn

Wednesday, 17 May 1972

0900 - Finalize Top Ten Concepts with Raw Ranking of #1 Most Benefit to #10 Least Benefit

1000 - Raw Ranking of Top Ten Concepts from #1 Least Cost to #10 Most Cost

(1030 Coffee)

1100 - Adjust Ranking to Integrate Benefit - Cost Considerations

1200 - Lunch

1300 - Identify Three Alternate Program Approaches to Implement Top Five Concepts from Adjusted Ranking

(1430 Coffee)

1500 - Affirm Consensus of Workshop Members for Draft of Proceedings

1530 - Interaction with Longer Range Studies

1600 - Adjourn

Note: Finalization of Workshop #8 Report by Chairman by 24 May 1972 with distribution to members for refinement or agreement by 1 June 1972.

FEDERAL COUNCIL FOR SCIENCE & TECHNOLOGY

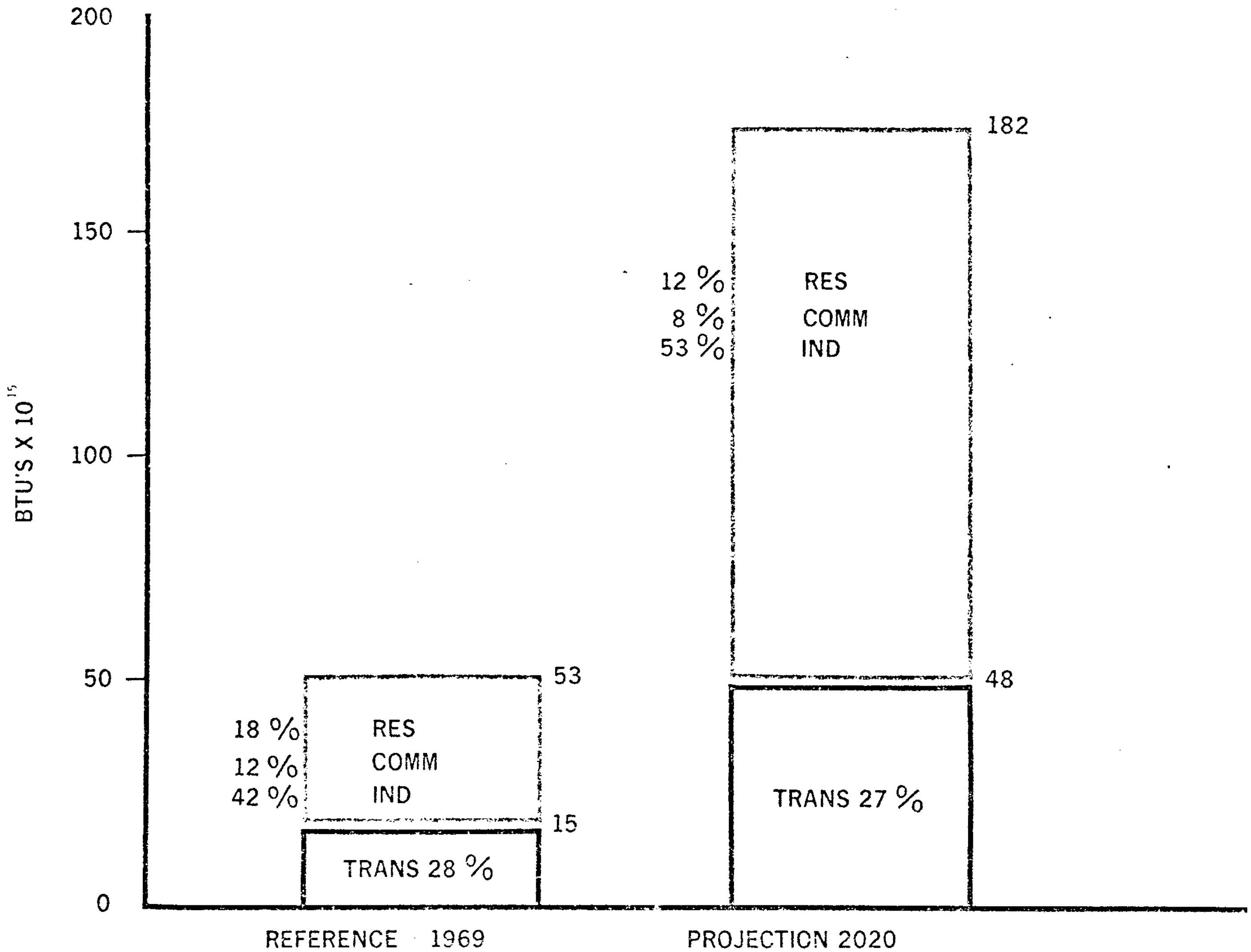
(Energy R&D Goals Committee)

10 Panels

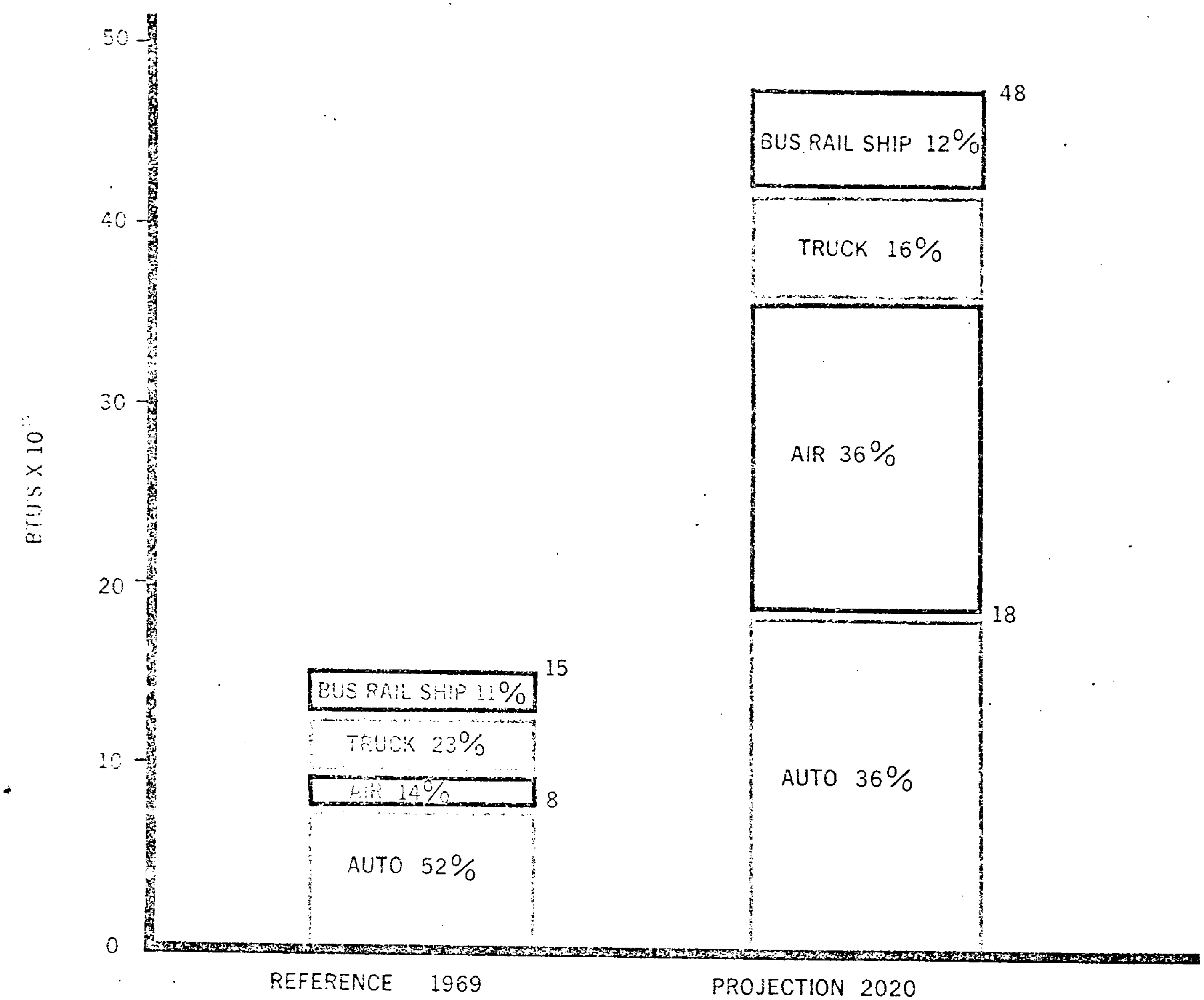
1. Fossil Fueled Central Power Plants (DOI/NAEP)
2. Low BTU Gas & Liquefaction of Coal (DOI)
3. Alternate Nuclear Breeders (AEC)
4. Fusion (AEC)
5. Elec Power Trans & Distribution (DOI/Elec Res Council)
6. Solar Energy (NSF & NASA)
7. Petroleum, Natural Gas, Shale (DOI/Nat Petroleum Council)
8. Transportation (DOT w/NASA & EPA)
9. Other Utilization Sectors (HUD)
10. Geothermal Energy (DOI/Geological Survey)

8 Workshops Within TEP

1. Energy Demand
2. Propulsion Alternatives at Lower Powers
3. Propulsion Alternatives at Higher Powers
4. Environmental Impact of Propulsion Alt
5. Electro Chemical R&D
6. Thermochemical & Thermo-mechanical R&D
7. Electric & Electro-Mechanical R&D
8. R&D for Fuel Economy in Auto Propulsion



U.S. ENERGY - END USE



U.S. TRANSPORTATION ENERGY DEMAND ON OIL

11 Apr 72
WSA

TRANSPORTATION ENERGY DEMAND DATA

MODE	1969 Transportation Analysis: SUBMODE	BPA Quad-rillion	GPA Bill	VMPG	VMPA Bill	PPV	1969 Payload Bill	Mean Load Factor	BPA ~ Quadrillion/MODE: Source	1969	1977	1985	2000	2020
Auto	Personal/Government/Business	7.81	60.00	14.20	850.0	1.2	102.0	.20	BR	7.81	10.20	12.10	14.70	17.60
									TNS[1]	7.81	11.10	14.00		
									FHWA	7.81	10.2	12.10	[illegible]	17.60
Bus	Intercity	.04	.30	6.00	1.8	14.0	25.0	.33	BR	.12	.17	.25	.41	1.20
	Urban (Includes School)	.08	.63	3.00	1.9	14.0	~26.0	.33	TNS	.12	.125	.13	.135	
									UMTA	.12	.17	.25	.41	1.20
Truck	Intercity - Freight	1.35	10.50	4.00+	44.0	7.5	327.0	?	BR	3.43	4.48	5.32	6.47	7.75
	Urban - Freight	.78	6.00	4.00−	24.0	3.5	82.0	?	TNS	3.43	5.05	6.60		
	Non-freight	1.30	10.00	10.00	100.0	--	-	-	FHWA	3.43	4.48	5.32	6.47	7.75
Rail (Oil/Electric)	Intercity - Passenger	.02	.12	.25	.030	175.0	5.0	.25	BR	.55/.02	.62/.06	.55/.17	.96/.29	2.01/.6
	Subway - Passenger	.02	.15	.25E	.04	160.0	6.0	.20	TNS	.55/.02	.69/.03	.83/.036		
	Freight	.53	4.00	.10	.4	1,800.0	720.0	~.70	FRA					
Air	International (B-747)	.39	3.00	.11	.33	70.0	23.0	.25	BR	2.09	5.00	10.50	14.50	17.30
	Domestic (B-727)	1.30	10.00	.25	2.5	40.0	100.0	.40	TNS	2.09	4.50	8.40		
	Freight (DC-6)	.39	3.00	.64	1.9	2.0	3.8	.10						
	Private	.01	.10	?	?	--	-	-	FAA					
Ship	Passenger (Queen Mary)	.04	.30	.003	.0011	1,200.0	1.3	.50	BR	.91	1.07	1.25	1.30	2.50
	Freight	.87	6.70	.01	.07	10,000.0	570.0	.80	TNS	.91	1.20	1.50		
									USCG					
TOTALS		14.90		-	--	--	-	-	BR	14.90	21.50	30.10	38.8	49.00
									TNS	14.90	22.70	31.50		
									ADMINS.					

1. This data is projected at constant VMPG and payload per vehicle.

E = Electric.

Note: 1. This is in-process worksheet under refinement in TEP. Right hand column headed BPA--is listing of 3 independent sources for each MODE of transportation.
2. Sources are: Brookhaven Report(BR); Transportation Needs Study(TNS) & DOT Cognizant Adminis (FHWA,etc).
3. Finalization is targeted for 5 Jun 72.

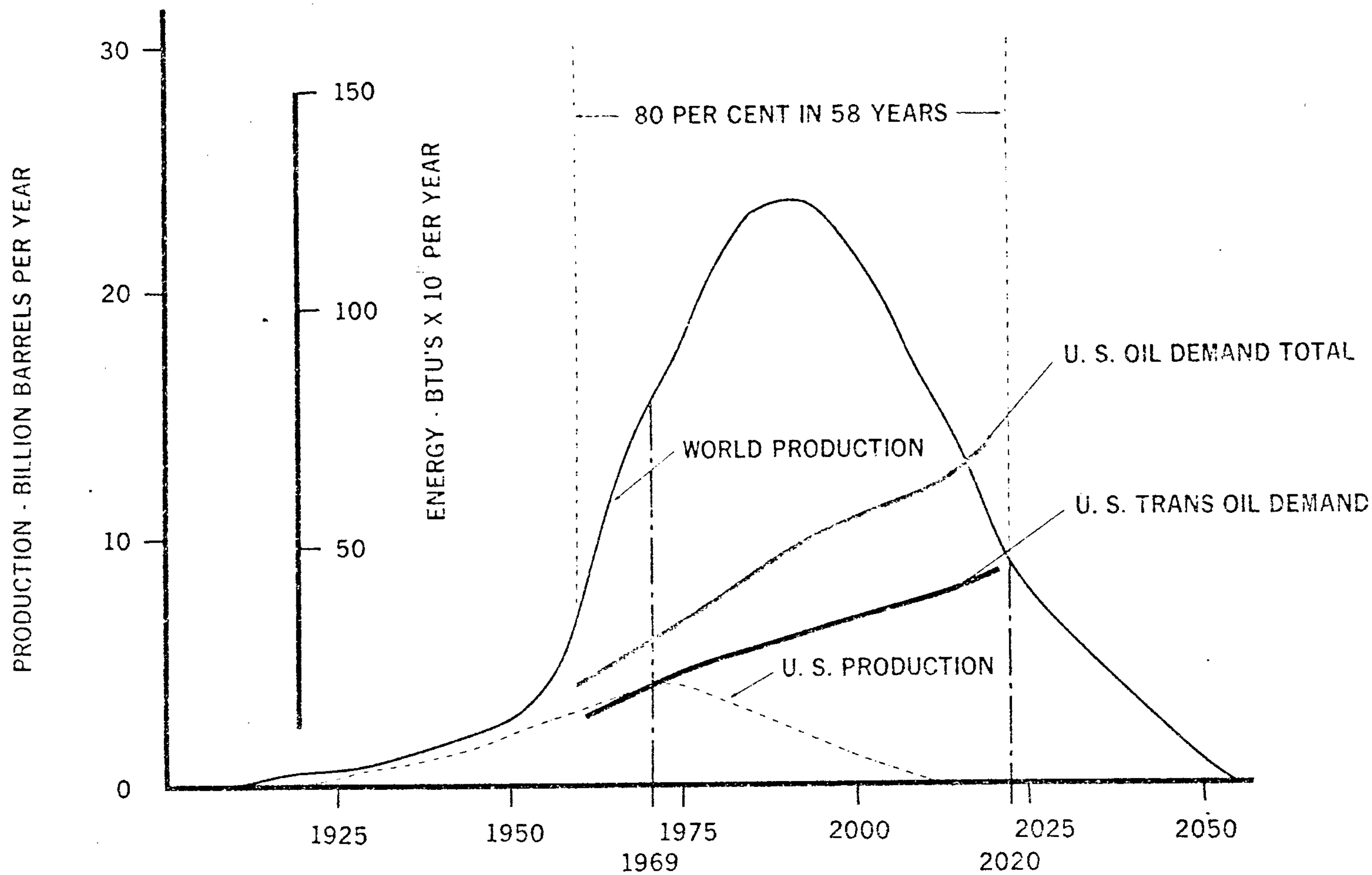
2 - Ap 72
cda

Analysis of Energy Consumption of Highway Vehicles
Related to Transportation Service, 1969

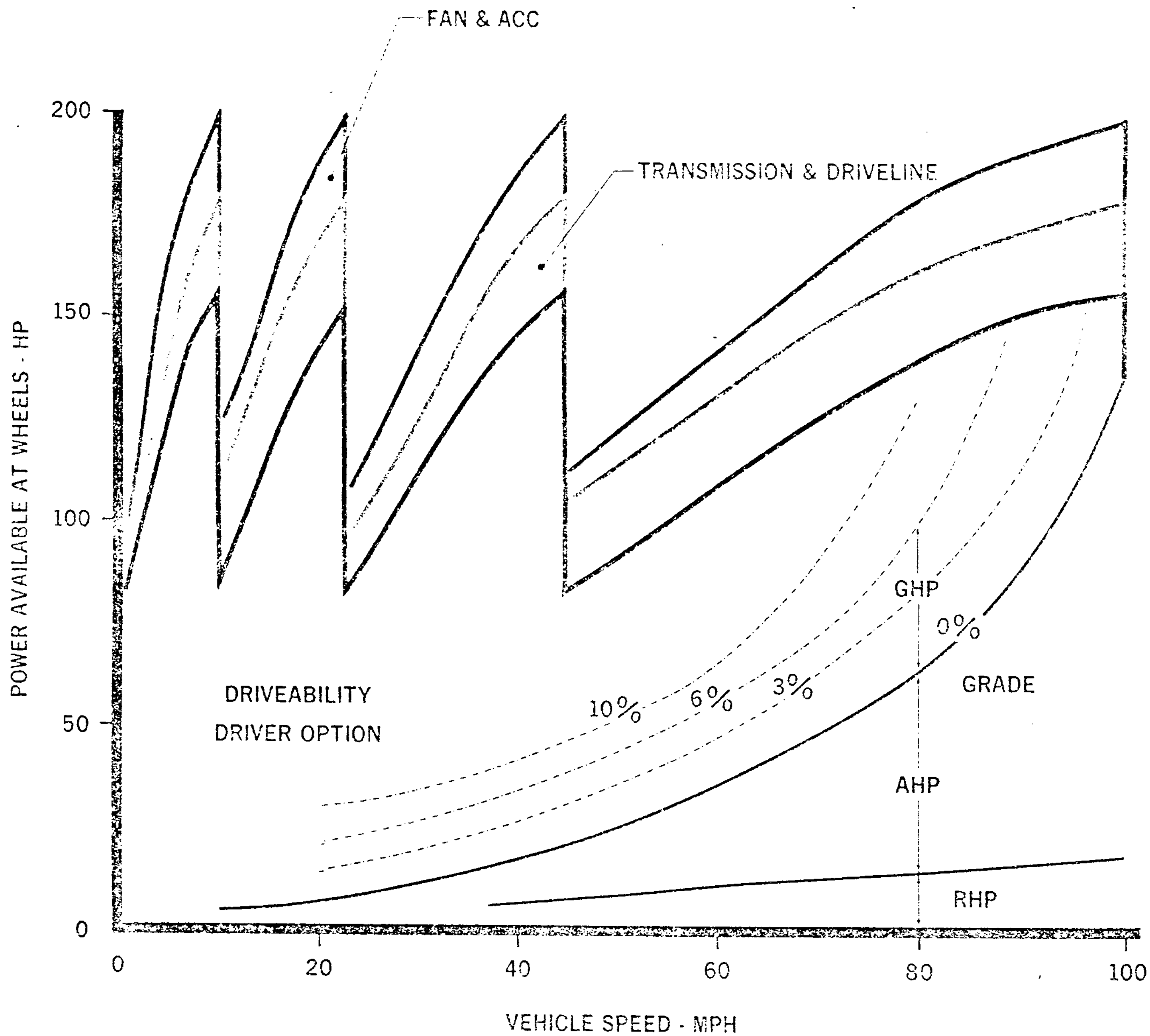
Vehicle type	Fuel [1/]	Number of vehicles	Vehicle miles of travel	Gallons of fuel	Average mpg	Energy in BTU's [2/]	Average loading (passengers/vehicle)	Transport service (passenger-miles)	Service per BTU (passenger-miles/BTU)
		(10^3)	(10^6)	(10^6)		(10^9)		(10^6)	(10^{-9})
Passenger vehicles		89,541.2	863,895	63,395	13.63	7,930,999	2.3	1,981,839	249,885
Passenger cars		86,861.3	849,633	62,325	13.63	7,790,625	2.2	1,869,193	239,929
Small	G	7,722.0	75,532	3,433	22.00	429,125	2.2	166,170	387,230
Standard & Comp.	G	79,139.3	774,101	58,892	13.14	7,361,500	2.2	1,703,022	231,342
Motorcycles		2,315.6	9,225	123	75.00	15,375	1.1	10,148	660,033
Buses		364.3	5,037	947	5.32	124,999	20.3	102,498	819,991
Transit		69.0	1,754	450	3.90	60,403	15.0	26,310	435,574
	G	23.0	547	149	3.67	18,625	15.0	8,203	440,430
	D	46.0	1,207	301	4.01	41,778	15.0	18,107	433,410
Intercity		21.3	1,253	207	6.05	28,318	20.9	26,188	924,783
	G	4.0	152	30	5.07	3,750	20.9	3,177	847,200
	D	17.3	1,101	177	6.22	24,568	20.9	23,011	936,625
School & other		274.0	2,030	290	7.00	36,278	24.6	50,000	1,378,246
	G	273.0	2,020	288	7.01	36,000	24.6	49,755	1,382,083
	D	1.0	10	2	5.00	278	24.6	245	881,295
							(Ton-miles/vehicle mile)	(Ton-miles)	(Ton-miles/BTU)
Cargo vehicles		17,871.0	206,680	24,727	8.36	3,158,495	2.6353	554,664	175,610
Single units		16,942.0	167,241	16,528	10.12	2,076,226	1.0851	181,473	87,405
+ 2-axle, 4-tire	G	12,265.0	118,741	9,424	12.60	1,178,000	0.3289	39,054	33,153
Other SU		4,677.0	48,500	7,104	6.83	898,226	2.9365	142,419	158,556
	G	4,435.0	43,332	6,363	6.81	795,375	2.5076	108,660	136,615
	D	242.0	5,168	741	6.97	102,851	6.5324	33,759	328,232
Combinations		929.0	39,439	8,199	4.81	1,082,269	9.2089	363,191	335,583
	G	624.0	18,173	4,040	4.50	505,000	6.4000	116,307	230,311
	D	305.0	21,266	4,159	5.11	577,269	11.6093	246,884	427,676
Total		107,412.2	1,070,575	88,122	12.15	11,089,494			

[1/] G = Gasoline, D = Diesel

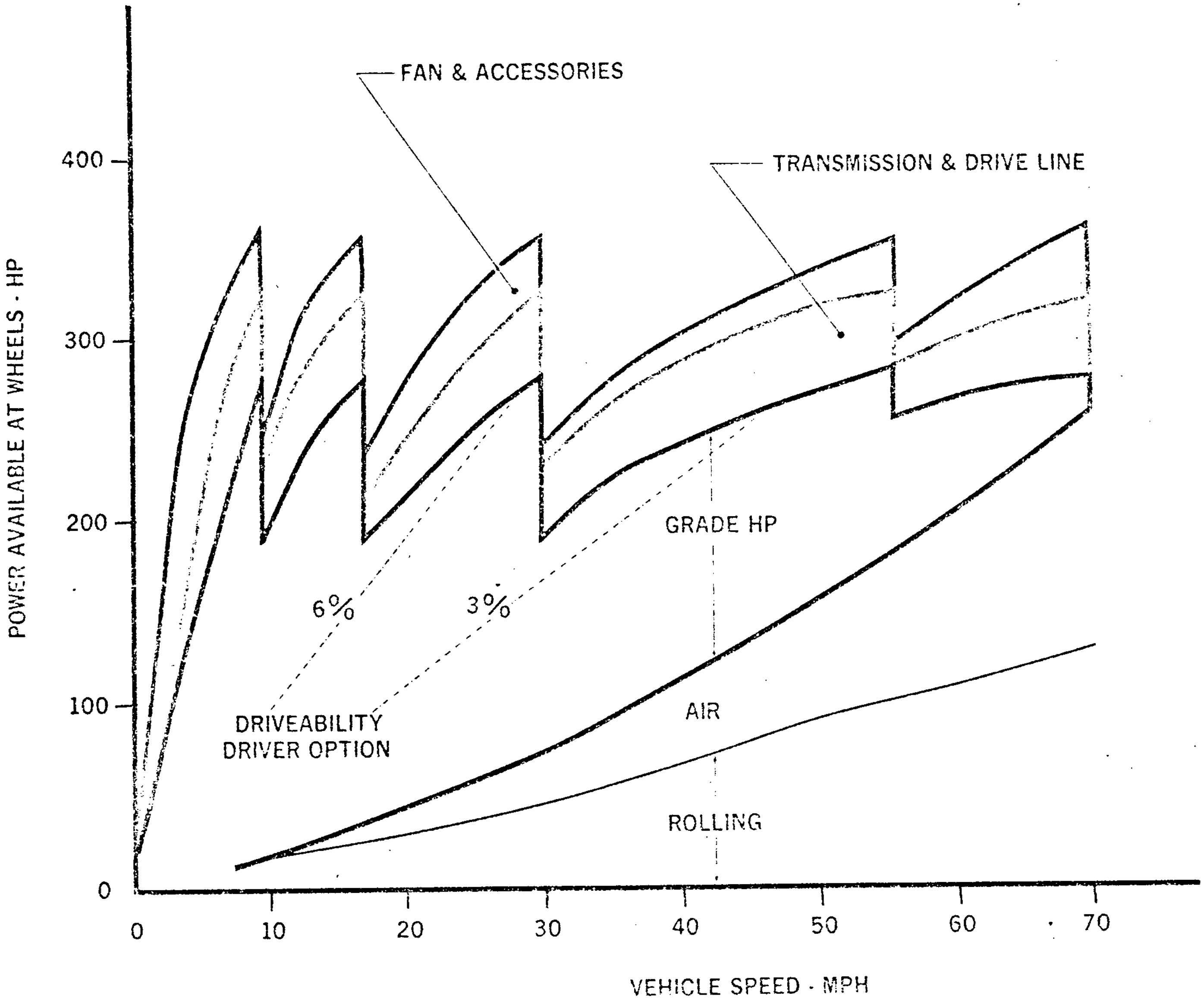
Prepared by Program Management Division


PRODUCTION - BILLION BARRELS PER YEAR
30
20
10
0
150
100
50
ENERGY - BTU'S X 10 PER YEAR
80 PER CENT IN 58 YEARS
WORLD PRODUCTION
U. S. OIL DEMAND TOTAL
U. S. TRANS OIL DEMAND
U. S. PRODUCTION
1925
1950
1975
1969
2000
2025
2020
2050

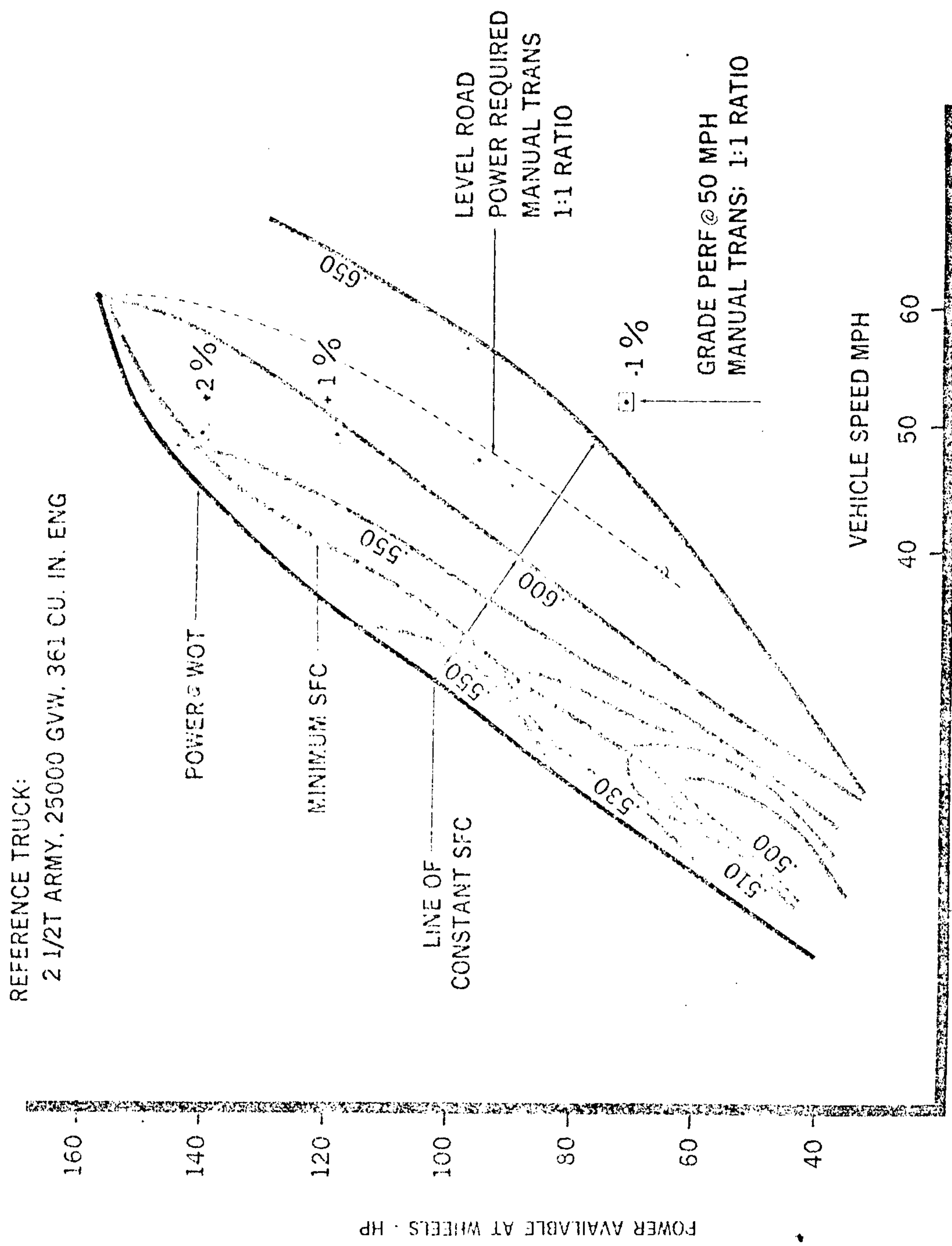
OIL MARKET



"REFERENCE AUTO" POWER - SPEED MAP



"REFERENCE TRUCK" POWER - SPEED MAP



TRANSMISSION - DRIVELINE MATCH

5 May 1972
"Strawman"
WSA

Principal Approaches to Conserve Fuel

1. Combustion refinements leading to improved efficiency (equivalent to reduced SFC from .5 to .4) could provide a 20% savings in total energy with no change to driveability and top speed limits. This is a significant potential savings. The major disadvantage is time. This approach would most likely mature in the 5-15 yr forward time period.

2. Reduce top speed from 80 to 60 mph would reduce by 25% the energy consumed by vehicles which operate in that speed regime. Histogram of vehicle--miles as function of speed would be required to address absolute savings. If 25% of total fuel were in this speed range, then .25 x .25 = .063 or 6.3% savings would be expected.

3. Driveability power option represents about 75% of the energy equivalent via combustion improvement from .5 to .4 SFC. Since this is output vs input, total energy savings would be .75 x .20 x 4 = .60 or 60%. Such a zero reserve power situation would be unsafe, provide negligible acceleration at all speeds and be nonsensical. Some compromise of driveability may be practical but at best it would be a part of the 60% potential. One might start thinking intuitively at the 20% level.

4. If all fan and accessory power demands were eliminated, this would result in a 10 x 4 = 40% potential fuel savings. This is a boundary limit. A practical achievable portion would be like 20%.

5. Transmission and driveline loss elimination would follow a similar pattern with boundary savings at 40%. These fixed losses are less movable. Hence total energy savings target of 10% is suggested.

6. Rolling resistance is mainly a function of tire loss. Evidence supports a total energy savings of about 10% with use of radial vs bias ply tire construction. This is a most attractive approach because it is technically the easiest to achieve on vehicles in service. Economics and availability of these tires in quantity required are uncertain.

7. Air resistance power demand is a function of vehicle shape, frontal area and speed. Size and shape of reference auto is fixed and the speed effect e.g., 80 to 60 mph is significant if a large part of auto usage is in this range. If the portion of population is small as assumed in para 2 above, then the total energy savings is low or about 6%.

8. Grade resistance power demand is a function of vehicle weight, road surface and grade and speed. At 40 mph, if the U.S. road system has a nominal grade of 3% vs 6%, the potential fuel saving would be about 25%. This is unlikely. However, the increased use of the Interstate Highways could result in some savings if speed were constant. The tendency to drive at higher speeds most likely will offset this effect.

9. Although variations of size and weight are excluded from Workshop #8 deliberations it is interesting to note that due to the basically linear effect, an auto of 1/2 weight or 2000 lbs with reduced size and reduced driveability could be expected to provide a fuel savings of 50 - 75%.

5 May 1972

Preliminary Ranking of Sensible Approaches		Independent Effect or Fuel Savings Potential (%)
1.	Reduce Wgt & Size & Driveability to 2000 lbs VW level	50 - 75%
2.	Reduce Fan and Accessory Power	20%
3.	Increase Engine Efficiency	20%
4.	Reduce "Driveability"	20%
5.	Change to Radial Tires	10%
6.	Reduce Transmission & Driveline Loss	10%
7.	Reduce Allowable Top Speed from 80 to 60 MPH	6%

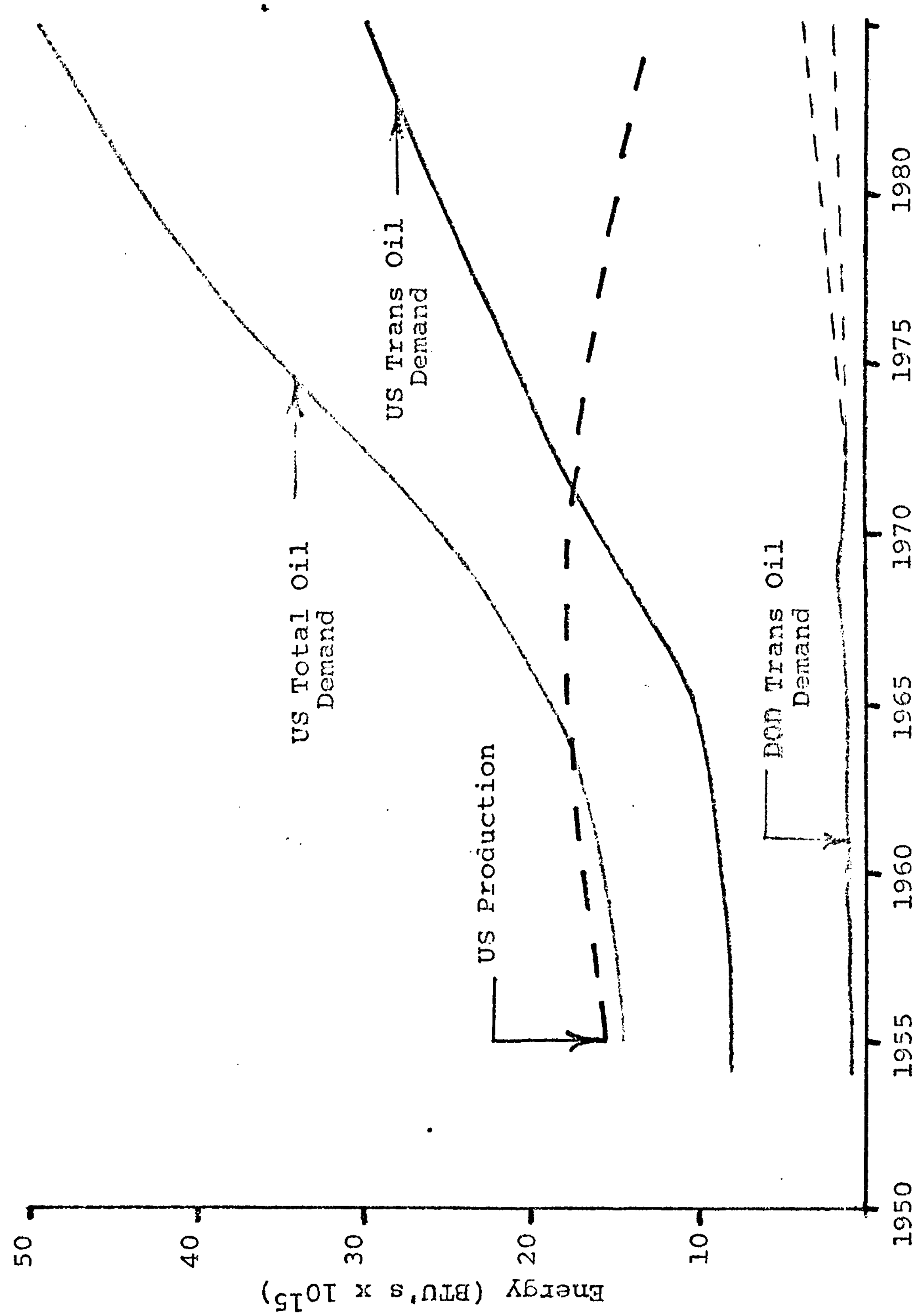
Notes:

a. Items 1 & 3 are eliminated from full consideration by Workshop #8 because 1 is not a technical choice due to present automobiles in service and 3 is most likely in the 5 - 15 yr foward time, not 0 - 5 yr.

b. Items 2, 4, 5, 6, & 7 warrant more complete consideration by Workshop #8.

c. Each item (2,4,5,6, &7) would in itself offer a practical fuel savings potential as listed in table. These individual effects are based on the premise that other parameters remain constant. Some of the items can be added and the potential savings would be additive to some uncertain extent.

d. If all items could achieve full effects and these effects were completely additive, the summation would be 66% potential fuel savings. If driveability were retained at the full referenced 1970 level then maximum apparent savings would be reduced to 46%. If reduction of speed to 60 mph were unacceptable then the apparent potential would decline to 40%. (Or the population mpg would be increased from 13.6 mpg to 1.4 x 13.6 = 19.0 mpg.)



DOD FUEL USAGE

DOD OIL USAGE

Yr	Transp & Other (Million Barrels)	Energy (BTU's x 10^{15})	DOD Split(Est) Other(20%)	Trans(80%)	% of US Trans Oil
1950	124.9	.70	.14	.56	
51	144.0	.80	.16	.64	
52	144.7	.81	.15	.65	
53	181.1	1.01	.20	.81	
54	193.4	1.07	.21	.86	
55	207.6	1.16	.23	.93	
56	219.0	1.22	.24	.98	
57	266.9	1.49	.30	1.19	
58	260.7	1.45	.29	1.16	
59	289.9	1.61	.32	1.29	
60	264.2	1.47	.29	1.18	
61	277.6	1.55	.31	1.24	
62	315.6	1.76	.35	1.41	
63	308.2	1.72	.34	1.38	
64	301.6	1.68	.33	1.35	
65	317.2	1.77	.35	1.42	
66	342.7	1.91	.38	1.53	
67	388.4	2.17	.43	1.74	
68	417.4	2.33	.46	1.87	
69	441.1	2.46	.49	1.97	13.2
70	382.1	2.13	.42	1.71	
71	336.6	1.87	.37	1.50	
72 Est	301.8	1.68	.33	1.35	
77 Est				2.0	8.7

CONVERSION FACTORS AND ENERGY EQUIVALENTS

Conversion Factors

1 Kw-hr (Kwh)	= 3412.8 Btu
1 Mw-yr	= 2.992×10^{10} Btu
1 HP-hr	= 2545 Btu
1 HP-hr	= 1.98×10^{6} ft lb
1 HP-hr	= 2.685×10^{6} Joules
1 Watt-hr	= 3600 Joules
1 HP	= 0.7455 Kw
1 HP	= 550 ft-lb/sec

Energy Equivalents

Although the energy content of some fuels can vary depending on their source, the following energy equivalents are generally accepted approximations.

COAL:

Anthractic	25.4×10^{6} Btu/ton
Bituminous	26.2×10^{6} Btu/ton
Sub-bituminous	19.0×10^{6} Btu/ton
Lignite	13.4×10^{6} Btu/ton

PETROLEUM:

Crude	5.61×10^{6} Btu/42 gal barrel
Residual	6.29×10^{6} Btu/42 gal barrel
Distillate Fuel Oil	5.83×10^{6} Btu/42 gal barrel
Gasoline (Motor)	5.25×10^{6} Btu/42 gal barrel
Gasoline (Aviation)	5.05×10^{6} Btu/42 gal barrel
Jet Fuel, Commercial	5.67×10^{6} Btu/42 gal barrel

NATURAL GAS (DRY):	1032 Btu/ft^3 at STP
NATURAL GAS LIQUIDS (AVG):	4.1×10^{6} Btu/42 gal barrel
FISSIONABLE MATERIAL:	74.0×10^{6} Btu/g U-235 fissioned

Working Papers of Workshop #8

APPENDIX D

CONTENTS

APPENDIX D

DISCUSSION OF DUAL ENGINE CONCEPT

The dual engine concept where four cylinders are used for local low speed operation and an additional four are employed only for conditions where high output is required is one of many schemes possible to offset the inherent low efficiency tendencies of the Otto cycle under highly throttled (low bmep) operating conditions. This problem has always faced automotive designers in the choice of powerplants; the compromise between larger engines offering higher performance and greater durability due to lower bmep and lower rpm operation, and small displacements offering superior fuel economy with the disadvantages of low performance, reduced durability noise and vibration problems resulting from the higher rpm necessary to meet vehicle power requirements. These factors are well known and bear no further mention.

Dealing specifically with the dual engine, there are two conceptual approaches. First, a common block eight-cylinder engine where four "reserve" cylinders are activated when additional power is required. When not in operation, these cylinders would reciprocate in the normal fashion but would not be supplied with fuel. The second would involve two separate powerplants coupled with a clutching mechanism. The "reserve engine" would only be started and engaged as required. On the surface, both approaches appear to have the potential to realize large gains in fuel economy; however, there are many problems to be considered.

I. Problems Common to Both Approaches

Control - The requirements for reserve power dictate a smooth and rapid transition from road load to acceleration power. For either case, a sophisticated control system would have to be developed to start and balance the operation of the reserve cylinders or engine. Such a fully automatic control, however, would undoubtedly defeat the purpose, since the driver will undoubtedly conform to his usual driving habits, resulting in near constant eight-cylinder operation.

Weight - All driveline components would have to be sized to withstand full power of the eight cylinders. There would also be the additional weight of control and/or clutching mechanisms. This would tend to reduce the fuel advantages of the dual engine under local operations and would result in poor four-cylinder performance.

Axle Ratio and Torque Converter Matching - The matching of the driveline to the dual engine would ultimately have to be a compromise between four and eight cylinder operation which would tend to reduce the expected gains.

Reserve Startup - The intermittent starting of the reserve cylinders would produce large amounts of hydrocarbon and carbon monoxide emissions since they would effectively be cold starts. These cylinders would also require cold fuel-air enrichment until they reached normal operating temperature, reducing fuel economy gains substantially.

II. Problems Unique to the "Common Block" Concept

Friction Loss - A considerable amount of power is required for the engine to overcome its own internal friction. If the common block approach were employed, the operation in the four-cylinder mode would suffer from friction loss from all eight cylinders. Data from a typical eight-cylinder engine at the WOT peak power point shows 156 BHP with 48 FHP. Very crudely estimating, this would result in a maximum four-cylinder output of 54 BHP. So, to provide suitable power for local driving in the four-cylinder mode, a relatively larger engine would be required. Even with the greater displacement, much of the operation in the fractional mode will be at or near WOT which requires an enriched power mixture. Both of these factors substantially reduce any fuel economy gains.

Practical Considerations - The major mechanical problems associated with this arrangement are listed without discussion:

- Flywheel - large enough for four-cylinder operation smoothness, excessively large for eight cylinders.

- Varnish and deposits in cold cylinders.

- Excessive oil consumption of cold cylinders due to large clearances when not in use.

- Separate carburetion and manifold systems.

- Valve control mechanism to prevent pumpimg losses in reserve cylinders.

- Controls.

III. Problems Unique to Separate Engine Concept

Weight - Two four-cylinder engines would weigh approximately 45% more than a comparable displacement eight-cylinder engine. Considering the coupling required, they would also require a substantially larger engine compartment, further increasing vehicle weight.

Clutch - The requirements for coupling are quite involved. The engagement must not only be smooth and controlled, it must also be positively indexed to provide an even spacing of firing events for eight-cylinder operation. Also, to realize maximum economy in eight-cylinder operation, it should be slipless once engaged.

Duality - Since both engines will be entirely independent, there will be a duplication of all components (e.g., distributor, oil pump).

Conclusions

Making the liberal assumption that all the technical problems associated with either system can be resolved, the separate engine concept must be considered the superior system since it does not give away large friction losses during fractional power operation. Again, referring to typical steady state engine test data, there is a theoretical potential gain in fuel economy as high as 25% during four-cylinder operation. However, the offsetting factors:

- increased weight,
- reduction in high load economy,
- increased proportion of operation under power enrichment conditions,
- increase cost of tune-up resulting in more infrequent maintenance,
- low performance,
- "cold start" of reserve engines with required enrichment and high emissions, and
- cost

reduce the actual gain of such a system to a marginal level.

To realize this small gain, the driver will have to exercise a tremendous amount of self-control by driving the vehicle in the four-cylinder mode for all local operation. Based on past experience, this will not be the case. If he is provided with a control system that will automatically engage the reserve engine, he will use the power at his convenience and fuel consumption will be worse than with the present engine. If a manual switch is provided, how can he be prevented from simply leaving it on the eight-cylinder position? Legislation?

The expenditures required as well as cost to the consumer simply cannot be justified in light of the potentially small gains and the very real possiblity that the application in every-day driving may even increase fuel consumption. Therefore, this concept does not warrant further consideration.

ACCESSORY DISCONNECT

1. Concept Outline: Automatic disconnect of accessories, when not required, to reduce parasitic friction. Could also include automatic disconnect of some accessories at or near wide open throttle to give acceptable emergency performance with a smaller, more economical engine.

2. Objective: To decrease the power demand and energy requirement of engine-vehicle accessories.

3. Present Status: Air conditioner disconnect by magnetic clutch is in production. Flex and viscous drive fans are in production.

   No known current development work.

4. Outline of Problem: Technical justifying the cost for the disconnect system by the small savings possible and the marketing justification of a high initial cost for a small savings in operating cost.

5. Recommended Action: Quantify possible gains and probable cost with the following concept variations.

   a. Common drive and engine-mounted disconnect to all accessories.

   b. Separate accessory-mounted disconnect at each accessory.

   c. Central hydraulic supply for all accessories.

6. Rank:

7. Estimated Cost:

8. Impact on Resources: 2 to 5 percent (rough estimate, system undefined)

9. Environmental and Ecological Impact: Reduction in exhaust emission approximately equal to resource saving (2 to 5%).

10. Conclusions and Recommendations:

VARIABLE LIMITATIONS

Constrained

Individually controlled vehicles
Operate on current highways (wheeled vehicles)
Otto cycle engine.
Maximum vehicle load capability unchanged.

Free

Vehicle weight
Aerodynamics
Power Train "tuning"
Energy storage
Accessory drive

Questionable

Emission performance

1. Coverage of operating modes
2. Two-car strategy
3. Trade-off with level

Government regulations
1. Tune-up
2. Car pooling
3. Restrictive gas tax

Fuel (major fuel must be gasoline for 5 years)
Safety (including implication of energy storage)
Damagability
Overall cost effective? (based on tax free or taxed fuel cost?)
Operational ease and convenience (auto. trans.?)

CONSTANT SPEED ROAD LOAD FUEL CONSUMPTION

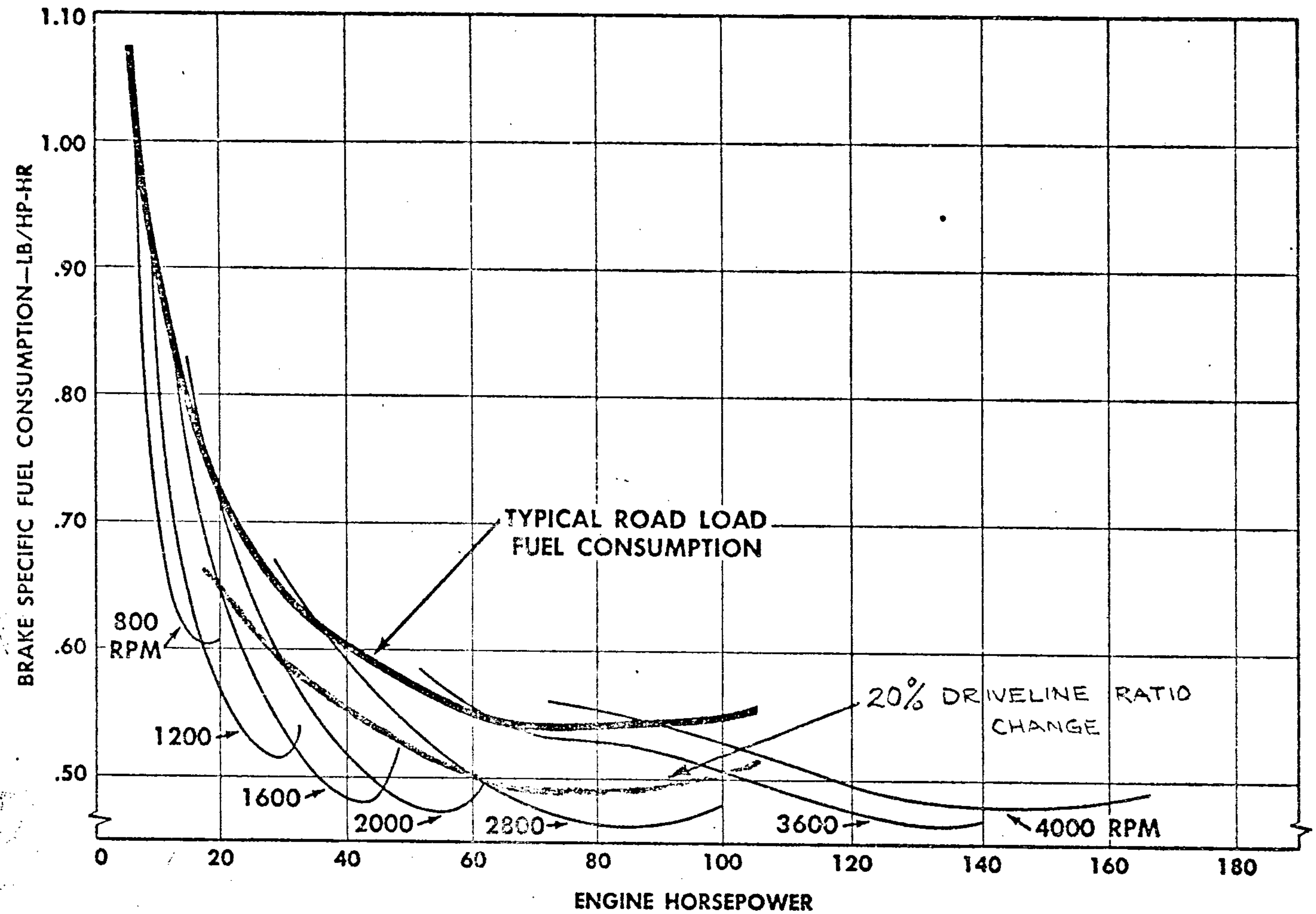


FIGURE 5.

UTILIZATION OF WASTE ENERGY FROM THERMAL REACTOR

Possible Applications for Waste Exhaust Heat:

I. Compress Intake Air Charge

II. Additional Power for Vehicle Drive

III. Power Source for Accessory Drive

IV. Heat Source for Accessories not Requiring Shaft Power

V. Store Energy for Use by Engine or Accessories as Needed

1. Concept

Utilize an exhaust turbine to compress the intake air charge.

2. Objective

Increase engine volumetric and thermal efficiency.

3. Present Status

a. On the shelf technology.

b. Supported by private industry in U. S. and abroad.

4. Problems

- Effective only at WOT operation.
- Significant increase in back pressure.
- Net improvement in economy minimal.
- Application would probably increase NO_x.
- High noise level.

5. Recommended Action

Technology currently available.

6. Rank

7. Estimated Effort

Minimal - adaptation to consumer vehicles required.

8. Impact on Resources

Not defined.

9. Environmental and Ecological Impact

Could increase NO_x and noise pollution.

10. Conclusions and Recommendations

1. <u>Concept</u>

Use a reaction or external heat engine to supplement horsepower at the flywheel.

Engine possibilities include:

Reaction Turbine

External Heat Engine

- Steam Engine
- Stirling Cycle
- Eccentric Drive Heat Engine
- Other

2. <u>Objective</u>

Increase efficiency of overall power system by obtaining direct power benefit from waste gases.

3. <u>Present Status</u>

a. No hardware development past concept stage.

b. Support level is nil.

4. <u>Problems</u>

- Small external heat engines not developed.
- Coupling to main engine shaft.
- Control of power to match engine output.
- Increase in power package size.
- Slight to large increase in back pressure.

5. Recommended Action

   a. $5M

   b. 1-3 years

6. Rank

7. Estimated Effort

   $10M and 3-5 years

8. Impact on Resources

   Not defined.

9. Environmental and Ecological Impact

   Possible increase in noise pollution.

1. Concept

Use an external heat or reaction engine to drive engine accessories which include the fan, water pump, air pump, power steering pump, alternator, and A/C compressor.

Engine possibilities include:

Reaction Engine

External Heat Engine

- Steam Engine
- Stirling Cycle
- Eccentric Drive Heat Engine
- Other

2. Objective

Drive complete accessory package with auxiliary engine (exhaust heat powered) allowing primary engine to be optimized more effectively for road load requirements.

3. Present Status

Technological base is established with regard to most engine concepts, but there is no activity toward this application.

4. Problems

- Small external heat engines not developed.
- Coupling to and control of accessory components.
- Exhaust heat and accessory requirement not necessarily consistent.
- Some back pressure penalty.
- Bulky underhood package.

5. Recommended Action

   a. $5M

   b. 1-3 years

6. Rank

7. Estimated Effort

   $10M and 3-5 years

8. Impact on Resources

   Not defined.

9. Environmental and Ecological Impact

   Possible increase in noise.

1. Concept

Use the waste exhaust heat for passenger heating in winter and cooling with aqueous NH_3 absorption refrigeration cycle or thermo-electric air conditioner in the summer.

2. Objective

Utilize waste heat with minimum interaction between the engine and the system being heated.

3. Present Status

Technology available but not currently supported.

4. Problems

- Quantity of heat utilized is small.
- Servel cycle not readily compatible with moving vehicle.
- Response time for both heating and cooling systems is slow.

5. Recommended Action

a. $500K

b. 1 year

6. Rank

7. Estimated Effort

$1M and 2 years

8. Impact on Resources

Not defined.

9. Environmental and Ecological Impact

None

1. Concept

Store energy with a mechanical or electrical accumulator for use by the engine or accessories on an as needed basis. Possibilities include the "super flywheel" and turbo-alternator-battery system.

2. Objective

Permit the primary power source to be designed for minimum average vehicle requirements with auxiliary power supplied under extreme conditions.

3. Present Status

a. No hardware development past design stage.

b. Support level is nil.

4. Problems

- Increase in under-hood volume.
- Increase in engine back pressure.
- Coupling and control of system.
- Increase in noise.

5. Recommended Action

a. $3M

b. 1-3 years

6. Rank

7. Estimated Effort

$5M and 5 years

8. Impact on Resources

Not defined.

9. Environmental and Ecological Impact

Possible increase in noise.

1. Concept Outline:

EGR and Spark Timing Optimization.

2. Objective:

To optimize the settings (or cut-out as appropriate) to provide maximum fuel economy within legal emission requirements.

3. Present Status:

a. Maturity: Various individual studies have been performed, but a generalized conclusion applicable to gasoline internal combustion engines is not available.

b. Support Level: Not known.

c. Contributors: Not known, probably all automotive firms in-house.

4. Outline of Problems:

a. Fuel economy depends on a number of interacting factors, for example: Percentage EGR; Spark Timing; Air/Fuel Ratio.

b. Assuming that a minimum performance level is a requirement, as is the meeting of emission levels, the problem appears to be the investigation of control circuitry to optimize EGR and spark timing.

5. Recommended Action: Initiate contracts to investigate and recommend control circuitry to optimize EGR and spark timing at various load levels (and air/fuel ratios) for: 4 cylinder, 6-cylinder in-line, and 8-cylinder Vee engines.

a. Funding Level: 10-man team on each of the three sizes of engine, or:

3 x 10 men x $50,000/man = $1,500,000 per year.

b. Timetable: 1 year for the three parallel studies (10 men each), followed by 1 year finalizing the control circuitry applicable to all engines (30 man effort). Total time: 2 years; total cost $3,000,000.

c. R&D Teams: Solicit industry for proposals.

6. Rank:

7. Estimated Effort, Schedule, and Cost to Reach Commercial Readiness:

a. R&D Phase:

2 years, $3,000,000 (see Item 5 above).

b. APE (Advanced Production Engineering) Phase: 2 years; $6,000,000 (based on R&D/APE ratios for engine development).

c. Tooling Costs: Not known at this time.

8. Impact on Resources:

Per Fig 12 attached, range in fuel consumption by adjustment of spark timing* is:

$$\Delta MPG = \frac{\text{Best Economy - Worst Economy}}{\text{Standard Engine Economy}}$$

$$= \frac{20.6 - 17}{20} = \frac{3.6}{20}$$

ΔMPG = 18% or ΔEnergy $\approx$ 17%

Per Fig 13 attached, range in fuel consumption by adjustment of EGR* is somewhat similar or:

$$= \frac{20.7 - 17}{19.9} = \frac{3.7}{19.9}$$

ΔMPG = 18.5% or ΔEnergy $\approx$ 17%

Since these factors are inter-related, results will not be additive, nor will they be as optimistic. A reasonable estimate would appear to be:

A 10% impact on resources.

9. Environmental and Ecological Impact:

None, since it is assumed that the same emissions levels will be obtained in either case.

10. Conclusions and Recommendations:

* Other factors being held constant.

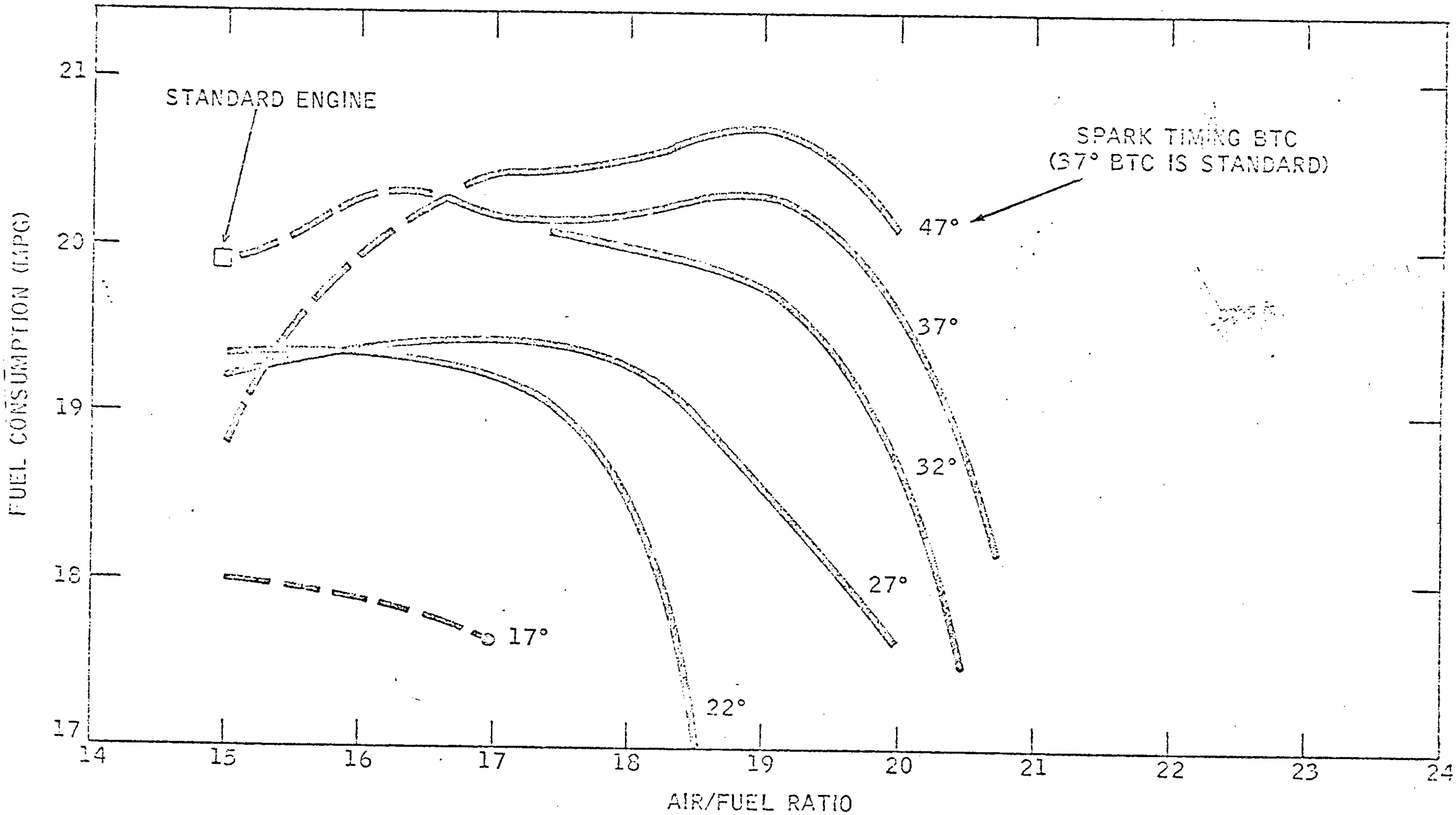


Figure 12. FUEL CONSUMPTION AS A FUNCTION OF AIR/FUEL RATIO AND SPARK TIMING, 50 MPH-ROAD LOAD

(SAE Paper 710164)

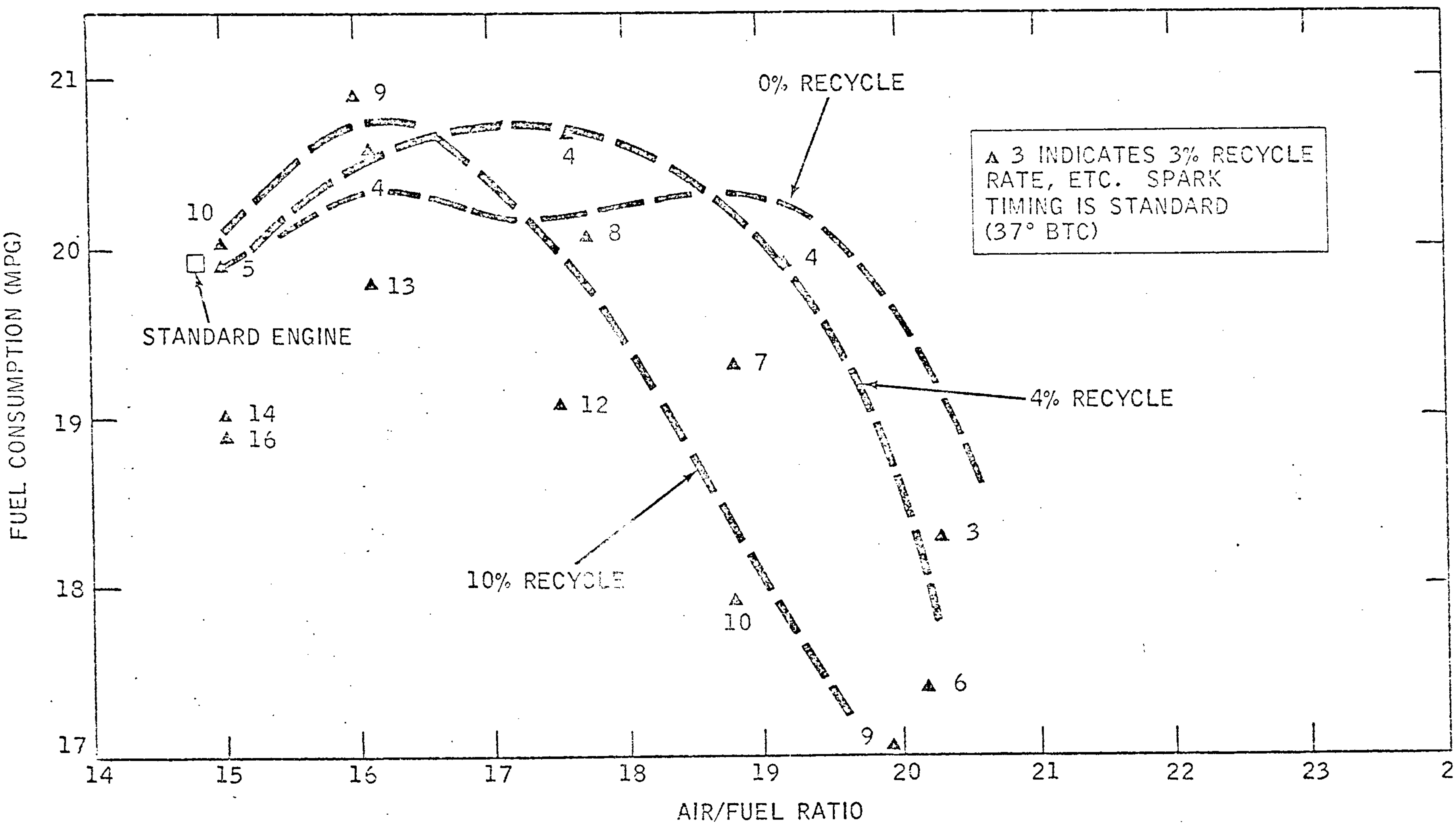


Figure 13. FUEL CONSUMPTION AS A FUNCTION OF AIR/FUEL RATIO AND RECYCLE RATE, 50 MPH-ROAD LOAD

(SAE Paper 710164)

U.S. DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION

SUBJECT: 1971 "Traffic Speed Trends" Report	FHWA NOTICE

November 22, 1971

HP-13

Attached is a copy of the 1971 "Traffic Speed Trends" report based on data collected by 38 States during 1970. As shown in the report, the trend in speeds decreased slightly during 1970. The average speed for all free-moving vehicles of 59.2 m.p.h. on main rural roads for 1970 was about 1 m.p.h. less than 1969. The average is based on speeds of 60.6 m.p.h. for passenger cars, 54.7 m.p.h. for trucks and 58.8 m.p.h. for buses.

The data indicate that more than 50 percent of the free-moving vehicles on straight, open sections of main rural roads exceed 60 m.p.h. in the majority of States and that the percent of vehicles exceeding 60 m.p.h. has nearly tripled in the past ten years. Average speeds over the past ten years have increased about 7 m.p.h.

In 1970, speeds on completed sections of the Interstate System averaged 63.8 m.p.h. for all vehicles. Twenty-two percent of the vehicles exceeded 70 m.p.h. on Interstate routes. This was almost double the percent exceeding 70 m.p.h. on all main rural roads, which include the Interstate System, and three times more than on rural primary roads.

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Attachment

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Regions
Divisions

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
WASHINGTON, D.C. 20590

TRAFFIC SPEED TRENDS

November 1971

Data resulting from speed studies conducted in 1970 by 38 States are summarized in the enclosed tables 1, 2 and 3. The information shown in the tables was collected on level, straight sections of main rural roads and on urban streets during off-peak periods of the day when traffic densities were low and drivers traveled at their desired speeds. Speed data have been collected by the States and summarized by the Federal Highway Administration since 1942. Speed information for Alaska and Hawaii are included in the tables for the first time. However, data from these States have been omitted from the totals in order to maintain comparable figures with previous years.

As shown in figures 1 and 2, nationwide average vehicle speeds in 1970 decreased from that of the previous year. The 1970 average speed for all regions was 59.2 m.p.h. compared to 60.0 m.p.h. for 1969 on main rural roads. This is the first time that a decrease has been recorded in nationwide average speeds since 1949. Figure 1 shows that average speeds decreased but that the percentage of vehicles exceeding 50 m.p.h. and 60 m.p.h. increased on a national basis. The percentage of vehicles exceeding 70 m.p.h. and 75 m.p.h., however, decreased. Average speeds decreased in all sections of the country, except for the eastern region which remained about the same as in 1969. Detailed data are listed in the tables showing average speeds and percentages of vehicles, by type, exceeding speeds from 35 m.p.h. to 75 m.p.h. in 5 m.p.h. increments by region and State. Data for completed Interstate sections are included.

As shown in figure 2, the average speeds for passenger cars and buses decreased about 0.5 m.p.h., while the average speed of trucks changed only slightly during 1970. The average speed of trucks is about 6 m.p.h. below passenger cars and about 4 m.p.h. below buses.

Table 1 summarizes speed data by State and regions for main rural roads. It shows an average speed for all vehicles of 59.2 m.p.h. which is almost 1 m.p.h. less than 1969. Average speeds over the past 10 years have increased about 7 m.p.h. Twelve percent of all vehicles traveled over 70 m.p.h. on main rural roads during 1970. Of the continental States reporting, Arizona and Nevada recorded the highest average speed, 64.6 m.p.h., while Teneessee recorded the lowest, 49.1 m.p.h.

Data resulting from speed studies on completed sections of the rural Interstate System by States are included in table 2. The average speed of all vehicles was 63.8 m.p.h., compared to 64.0 m.p.h. for 1969. On these completed Interstate routes, 69 percent of the vehicles traveled over 60 m.p.h. and 22 percent traveled over 70 m.p.h.

Table 3 includes data for various types of highways and some individual freeways. It shows that average speeds on the completed portions of the rural Interstate System are about 6 m.p.h. greater than on the existing rural Interstate traveled-way sections. The Interstate traveled-way consists of older roads which connect completed portions of the Interstate System and presently serve the traffic which will use the Interstate System when completed. The information also indicates that average speeds on completed rural Interstate routes are about 5 m.p.h. greater than on existing main rural roads. The main rural category includes toll and free sections of completed rural Interstate, rural Interstate traveled-way, and other primary roads.

TABLE 1.--AVERAGE SPEEDS OF VEHICLES AND PERCENTAGES OF VEHICLES TRAVELING IN EXCESS OF VARIOUS SPEEDS, ON LEVEL, STRAIGHT SECTIONS OF MAIN RURAL ROADS, INCLUDING THE INTERSTATE SYSTEM FOR 1970.

Region and State	Average speed				Speed exceeded																																			
					35 m.p.h.				40 m.p.h.				45 m.p.h.				50 m.p.h.				55 m.p.h.				60 m.p.h.				65 m.p.h.				70 m.p.h.				75 m.p.h.			
	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus
	Miles per hour				Percentage of vehicles																																			
EASTERN REGIONS																																								
NEW ENGLAND																																								
Connecticut	50.3	50.7	48.9	49.8	100	100	99	100	90	92	86	91	70	71	63	74	44	46	38	39	23	24	22	17	10	11	5	4	3	4	0	0	-	-	-	-	-	-	-	-
Maine	57.3	57.8	53.9	54.4	100	100	99	100	98	99	97	95	92	93	88	90	77	77	71	65	56	58	45	46	39	41	21	27	22	24	5	10	9	11	0	5	-	-	-	-
New Hampshire ...	56.1	56.4	52.1	56.3	98	98	97	87	93	93	92	80	56	87	83	73	67	68	57	67	55	55	40	67	34	36	14	53	23	25	7	40	7	7	1	0	3	3	0	0
Rhode Island	56.9	57.7	52.8	54.2	99	100	97	100	98	99	93	100	94	96	89	86	87	90	75	75	65	65	47	62	42	47	19	25	12	14	2	0	4	4	0	0	1	1	0	0
MIDDLE ATLANTIC:																																								
New Jersey	54.0	54.6	52.8	52.3	100	100	99	100	98	99	97	100	89	92	83	72	73	81	72	67	45	47	43	39	26	27	23	28	4	5	2	5	2	2	0	0	0	0	0	0
New York	55.5	56.2	51.9	55.5	100	100	99	95	99	99	97	95	93	94	87	92	78	80	65	78	53	57	37	45	36	40	18	30	16	19	5	16	4	5	1	0	1	1	0	0
Pennsylvania	52.5	53.4	50.5	51.3	99	99	99	99	96	97	94	91	84	87	79	75	61	65	52	51	32	37	22	32	13	16	5	13	3	4	1	3	1	1	0	0	-	-	-	-
SOUTH ATLANTIC:																																								
Florida	57.4	58.2	54.7	-	100	100	100	-	98	98	97	-	94	95	91	-	79	81	70	-	63	67	49	-	35	39	20	-	19	22	9	-	4	5	1	-	1	2	0	-
North Carolina ..	57.0	58.1	54.3	64.3	100	100	99	100	98	98	97	100	92	95	86	100	78	84	64	100	55	62	39	100	29	34	17	65	10	12	4	45	-	-	[illegible]	[illegible]	-	-	-	-
South Carolina ..	50.3	60.9	58.7	-	100	100	100	-	100	100	100	-	99	98	99	-	93	94	95	-	80	81	77	-	46	50	34	-	17	22	7	-	7	9	[illegible]	[illegible]	-	-	-	-
Virginia	61.9	63.2	55.5	64.6	100	100	100	99	99	100	98	99	97	98	92	99	91	94	76	96	78	84	50	89	55	62	17	76	31	37	4	44	11	13	1	9	-	-	-	-
West Virginia ...	54.6	55.3	51.1	52.2	99	99	97	100	94	95	86	100	83	85	74	77	65	68	51	46	46	49	33	31	28	31	17	23	15	17	5	8	7	8	1	0	2	2	0	0
Average	56.2	56.9	53.1	55.5	100	100	99	98	97	97	95	95	89	91	85	84	75	77	66	68	54	58	42	53	33	36	18	34	15	17	4	17	6	7	1	2	1	2	0	0
CENTRAL AND WESTERN REGIONS																																								
EAST NORTH CENTRAL:																																								
Illinois	60.9	63.7	54.8	57.0	100	100	100	100	99	100	99	100	97	99	95	39	92	95	84	87	78	88	55	64	60	75	26	50	39	53	8	28	19	26	2	0	-	-	-	-
Indiana	63.1	65.5	57.5	-	100	100	100	-	100	100	99	-	99	99	96	-	95	98	88	-	85	93	67	-	69	81	40	-	45	57	15	-	22	29	3	-	7	9	1	-
Michigan	60.3	61.4	55.3	61.4	99	100	99	98	98	98	97	98	94	94	91	96	86	88	78	89	71	75	52	74	51	56	22	62	29	35	4	38	13	15	0	13	3	4	0	0
Ohio	61.9	63.8	54.4	-	-	-	-	-	-	-	-	-	-	-	-	-	91	95	80	-	77	85	47	-	61	71	19	-	39	48	4	-	20	25	1	-	5	7	0	-
EAST SOUTH CENTRAL:																																								
Mississippi	56.1	58.1	51.6	50.9	99	99	98	99	98	99	96	98	89	92	82	52	82	87	72	50	62	70	43	46	49	58	28	39	25	32	9	24	14	18	6	12	3	4	1	1
Tennessee	49.1	50.8	45.1	50.1	86	89	82	90	74	77	67	81	63	67	52	69	[illegible]	55	36	52	37	43	22	42	20	26	8	22	11	15	3	6	2	3	1	0	1	1	0	0
WEST NORTH CENTRAL:																																								
Kansas	64.0	66.2	57.3	-	100	100	100	-	99	100	98	-	97	99	92	-	95	97	82	-	85	92	65	-	69	80	35	-	47	58	15	-	26	32	6	-	9	11	1	-
Minnesota	63.3	64.7	57.6	64.8	100	100	100	100	99	100	99	100	98	99	95	100	[illegible]	96	83	98	84	89	63	98	63	72	30	89	38	45	9	48	15	19	1	11	5	6	0	2
Missouri	62.1	63.8	58.0	65.7	100	100	100	100	99	99	98	100	98	99	96	100	[illegible]	95	86	100	79	85	65	100	58	68	34	80	34	43	11	60	12	16	3	9	-	-	-	-
Nebraska	60.8	61.8	56.2	63.2	100	100	100	100	100	100	99	100	97	98	95	100	[illegible]	93	84	100	78	81	61	91	55	61	28	72	28	33	6	45	12	14	1	4	4	4	0	1
North Dakota	62.9	65.0	56.5	-	99	99	98	-	98	99	95	-	94	97	87	-	[illegible]	94	76	-	78	85	57	-	63	72	34	-	40	48	15	-	22	27	5	-	9	12	2	-
South Dakota	64.0	65.1	60.4	64.7	100	100	100	100	99	99	99	100	96	96	96	97	[illegible]	92	90	92	80	82	74	92	64	69	46	87	42	49	19	44	22	27	6	5	7	9	1	0
WEST SOUTH CENTRAL:																																								
Arkansas	55.6	57.0	53.4	54.1	100	100	100	100	98	99	98	94	95	97	93	91	[illegible]	90	74	68	59	70	41	43	18	24	10	23	8	11	3	14	1	1	0	3	0	0	0	0
Oklahoma	58.9	59.7	53.6	60.6	99	99	98	98	97	98	95	98	93	94	85	87	[illegible]	88	76	85	70	73	51	77	55	59	29	62	26	29	6	46	12	14	1	28	2	3	0	0
Texas	62.3	64.2	57.5	63.4	100	100	100	99	99	100	97	99	98	99	94	98	[illegible]	95	80	90	83	89	67	83	56	67	30	68	41	50	17	57	12	15	3	15	5	6	1	1
MOUNTAIN:																																								
Arizona	64.6	66.0	57.6	67.9	100	100	100	100	100	100	99	100	98	99	93	100	95	98	83	100	58	93	63	100	73	82	30	96	43	49	10	84	21	25	1	16	5	6	0	0
Colorado	62.0	62.5	55.6	-	-	-	-	-	99	100	97	-	97	98	88	-	[illegible]	93	72	-	80	82	53	-	61	64	30	-	35	37	10	-	12	13	1	-	-	-	-	-
Idaho	58.7	60.7	54.7	58.3	99	100	98	97	95	97	92	97	90	94	85	90	[illegible]	84	67	78	64	72	49	70	42	51	25	46	28	35	13	15	11	15	3	2	4	6	1	2
Montana	64.0	67.1	56.9	60.4	100	100	99	100	99	100	98	100	97	99	93	93	[illegible]	96	78	92	79	89	55	85	62	76	30	46	42	54	14	24	26	35	5	0	12	17	2	0
Nevada	64.6	66.9	59.7	66.4	100	100	99	100	99	100	97	100	98	100	96	100	95	98	90	100	87	92	78	88	72	81	53	82	51	61	28	76	31	39	13	35	14	19	4	0
Utah	60.2	61.0	56.0	60.0	-	-	-	-	-	-	-	-	97	97	92	100	[illegible]	91	77	89	74	78	56	75	52	55	31	64	28	30	9	14	11	13	2	0	-	-	-	-
PACIFIC:																																								
California	59.6	60.6	54.3	62.9	99	-	-	-	96	-	-	-	93	-	-	-	37	-	-	-	74	-	-	-	53	-	-	-	28	-	-	-	10	-	-	-	2	-	-	-
Oregon	58.6	61.2	53.6	-	100	100	100	-	99	100	98	-	96	98	92	-	83	91	69	-	62	73	39	-	37	52	7	-	21	31	1	-	9	14	0	-	2	4	0	-
Washington	60.9	61.7	55.2	59.7	100	100	100	100	98	99	97	100	96	97	93	100	88	89	75	98	76	79	52	86	51	55	20	39	33	37	5	12	12	13	0	0	-	-	-	-
Average	60.8	62.4	55.5	60.6	99	99	99	99	97	98	96	98	94	96	90	92	88	91	77	87	75	81	55	77	55	63	28	60	33	41	10	37	15	19	3	8	5	7	1	1
ALL ABOVE STATES																																								
AVERAGE	59.2	60.6	54.7	58.8	99	99	99	99	97	98	96	97	93	94	88	89	83	86	73	80	68	73	51	68	47	54	24	51	27	33	8	30	12	16	2	6	4	6	1	0
Alaska	51.1	51.4	50.2	43.9	96	96	95	93	86	87	85	57	69	70	68	29	43	45	37	0	18	19	15	0	7	7	3	0	2	2	1	0	1	1	0	0	0	0	0	0
Hawaii	43.8	43.8	-	-	-	-	-	-	59	59	-	-	-	-	-	-	20	20	-	-	-	-	-	-	4	4	-	-	-	-	-	-	0	0	-	-	-	-	-	-

- Indicates data not available.

TABLE 2.--AVERAGE SPEEDS OF VEHICLES AND PERCENTAGES OF VEHICLES TRAVELING IN EXCESS OF VARIOUS SPEEDS, ON LEVEL, STRAIGHT SECTIONS OF THE COMPLETED PORTIONS OF THE RURAL INTERSTATE SYSTEM FOR 1970.

Region and State	Average speed				Speed exceeded: 35 m.p.h.				40 m.p.h.				45 m.p.h.				50 m.p.h.			
	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus
	Miles per hour				Percentage of vehicles															
NEW ENGLAND:																				
Connecticut	61.8	62.9	58.7	61.3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Maine	65.4	66.1	59.5	63.1	100	100	100	100	100	100	100	100	100	100	99	100	99	99	96	87
New Hampshire ...	63.8	64.1	59.3	65.3	100	100	100	100	100	100	100	100	100	100	100	100	95	95	90	58
Rhode Island	59.8	60.9	54.1	55.3	100	100	100	100	100	100	97	100	99	100	94	100	96	99	81	83
MIDDLE ATLANTIC:																				
New Jersey	58.4	59.4	57.1	56.3	100	100	100	100	100	100	99	100	96	98	94	86	93	95	90	86
New York	62.2	62.7	58.0	60.0	100	100	99	83	100	100	99	83	99	100	97	83	98	99	94	83
Pennsylvania	58.8	60.2	55.6	61.4	100	100	100	100	100	100	100	100	99	99	98	100	93	96	86	96
SOUTH ATLANTIC:																				
Florida	63.6	64.6	58.9	-	100	100	100	-	100	100	99	-	99	99	98	-	94	96	87	-
North Carolina ..	63.5	64.6	60.8	64.5	100	100	100	100	100	100	100	100	100	100	99	100	97	99	93	100
South Carolina ..	67.2	68.8	62.0	-	100	100	100	-	100	100	100	-	100	100	100	-	99	100	97	-
Virginia	64.5	66.0	57.3	66.8	100	100	100	99	100	100	99	99	99	100	96	98	96	98	86	97
West Virginia ...	62.7	64.3	57.0	59.7	100	100	99	100	99	100	97	100	98	99	93	100	91	94	78	67
EAST NORTH CENTRAL:																				
Illinois	63.8	67.0	56.4	62.0	100	100	100	100	100	100	100	100	99	100	98	100	97	99	92	100
Indiana	67.0	69.2	60.5	-	100	100	100	-	100	100	99	-	100	100	99	-	99	100	96	-
Michigan	63.4	65.0	57.1	66.0	100	100	100	100	100	100	99	100	98	99	95	100	94	96	87	100
Ohio	65.0	64.9	56.4	-	-	-	-	-	-	-	-	-	-	-	-	-	97	99	90	-
EAST SOUTH CENTRAL:																				
Mississippi	61.7	63.7	56.3	65.8	100	100	99	100	100	100	99	100	98	99	95	100	96	98	90	100
Tennessee	57.3	59.2	52.0	56.5	98	99	94	100	96	98	90	91	91	95	82	86	81	87	65	80
WEST NORTH CENTRAL:																				
Kansas	67.5	69.5	58.3	-	100	100	100	-	100	100	100	-	99	100	95	-	97	99	88	-
Minnesota	64.6	65.9	57.5	66.2	100	100	100	100	100	100	100	100	99	100	94	100	95	97	83	100
Missouri	67.0	68.7	61.7	68.8	100	100	100	100	100	100	100	100	100	100	100	100	100	100	98	100
Nebraska	66.6	68.7	58.4	66.1	100	100	100	100	100	100	100	100	100	100	98	100	98	99	93	100
North Dakota	67.6	69.1	60.8	-	100	100	100	-	100	100	99	-	99	99	97	-	96	98	91	-
South Dakota	67.9	69.4	62.7	66.8	100	100	100	100	100	100	100	100	100	100	100	100	100	100	98	100
WEST SOUTH CENTRAL:																				
Arkansas	61.6	62.9	58.9	59.2	100	100	100	100	100	100	100	100	100	100	100	100	97	98	95	89
Oklahoma	63.7	64.5	57.2	62.4	100	100	99	100	100	100	99	100	98	99	93	100	97	98	87	100
Texas	62.8	64.5	58.3	62.8	100	100	100	100	99	100	98	100	99	100	96	98	92	95	85	84
MOUNTAIN:																				
Arizona	67.5	69.3	59.6	68.2	100	100	100	100	100	100	99	100	99	100	96	100	97	99	88	100
Colorado	64.2	64.8	57.0	-	-	-	-	-	100	100	98	-	99	99	93	-	95	97	80	-
Idaho	64.4	66.5	59.3	62.5	100	100	99	100	99	100	97	100	98	99	95	100	92	95	84	100
Montana	64.2	67.6	56.7	60.6	100	100	99	100	99	100	98	100	97	99	92	86	90	96	77	86
Nevada	65.8	68.4	60.2	68.8	100	100	100	100	100	100	99	100	99	100	97	100	96	99	91	100
Utah	64.2	64.8	60.0	-	-	-	-	-	-	-	-	-	99	99	100	-	97	98	94	-
PACIFIC:																				
California	61.8	63.0	55.6	63.6	100	-	-	-	100	-	-	-	99	-	-	-	96	-	-	-
Oregon	62.8	66.1	56.2	-	100	100	100	-	100	100	100	-	100	100	99	-	96	99	89	-
Washington	63.5	64.6	57.0	59.7	100	100	100	100	100	100	99	100	99	100	97	100	96	98	85	98
AVERAGE Above Stated	63.8	65.4	58.1	63.0	100	100	100	99	100	100	99	99	99	99	96	98	96	98	89	93
Alaska 5/	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hawaii	56.0	56.0	-	-	-	-	-	-	97	97	-	-	-	-	-	-	76	76	-	-

Region and State	Speed exceeded: 55 m.p.h.				60 m.p.h.				65 m.p.h.				70 m.p.h.				75 m.p.h.				Speed limit 1/	Number of stations
	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus		
	Percentage of vehicles																					
NEW ENGLAND:																						
Connecticut	96	98	90	100	49	59	23	33	20	27	2	0	-	-	-	-	-	-	-	-	60	1
Maine	94	95	81	87	80	84	48	75	54	58	14	37	24	27	1	25	-	-	-	-	70	5
New Hampshire ...	89	90	76	88	68	70	33	88	50	52	17	75	15	16	3	0	6	6	1	0	70 2/	4
Rhode Island	83	88	59	67	58	66	18	17	19	22	0	0	4	5	0	0	0	0	0	0	65	1
MIDDLE ATLANTIC:																						
New Jersey	75	77	72	57	54	59	46	57	10	15	3	14	4	7	0	0	1	1	0	0	60	1
New York	91	93	75	58	75	79	47	50	38	41	14	33	10	11	2	0	1	2	0	0	65 2/	11
Pennsylvania	72	81	51	93	38	49	15	59	12	16	3	19	2	2	0	0	-	-	-	-	65 2/	3
SOUTH ATLANTIC:																						
Florida	88	91	72	-	65	70	39	-	43	48	18	-	12	14	2	-	4	5	1	-	70	4
North Carolina ..	90	95	78	100	67	75	48	91	30	37	14	64	-	-	-	-	-	-	-	-	65	5
South Carolina ..	97	99	91	-	84	91	62	-	62	74	25	-	31	40	1	-	-	-	-	-	70	3
Virginia	88	94	63	95	69	79	23	90	43	52	5	62	16	20	1	13	-	-	-	-	65	3
West Virginia ...	82	88	62	67	63	70	37	67	38	45	11	33	19	23	3	0	5	6	0	0	70	2
EAST NORTH CENTRAL:																						
Illinois	88	97	66	88	73	90	32	75	53	71	10	50	28	39	3	0	-	-	-	-	70	9
Indiana	94	98	82	-	83	92	58	-	66	79	27	-	38	49	7	-	13	17	2	-	70	4
Michigan	83	88	63	86	63	72	29	79	41	50	5	57	20	25	0	29	6	7	0	0	70	6
Ohio	69	95	60	-	75	86	27	-	54	64	6	-	29	35	1	-	7	9	0	-	70	19
EAST SOUTH CENTRAL:																						
Mississippi	85	91	69	94	74	83	49	91	45	56	17	78	28	35	7	53	6	8	1	0	70	14
Tennessee	66	74	43	69	38	45	16	40	21	26	6	14	5	6	2	0	2	2	0	0	75	5
WEST NORTH CENTRAL:																						
Kansas	93	98	69	-	82	91	40	-	65	75	16	-	43	51	7	-	17	21	1	-	75	3
Minnesota	87	92	64	100	70	77	32	92	46	53	10	67	22	25	2	17	8	9	0	0	70	3
Missouri	96	99	88	100	84	93	57	100	60	73	22	100	26	33	6	0	-	-	-	-	70	3
Nebraska	92	97	75	100	81	90	44	92	61	74	13	83	37	46	0	0	13	17	0	0	75	2
North Dakota	91	94	80	-	79	85	51	-	59	67	23	-	38	45	9	-	19	22	4	-	75 2/	5
South Dakota	94	96	88	100	81	87	60	96	59	69	26	54	34	41	8	8	12	15	1	0	75	6
WEST SOUTH CENTRAL:																						
Arkansas	88	93	77	56	64	74	42	44	32	40	14	33	3	4	0	11	0	0	0	0	75	3
Oklahoma	87	89	71	100	77	80	50	56	49	53	12	44	26	29	2	11	4	5	0	0	70	11
Texas	85	90	71	84	58	68	32	64	42	51	15	53	12	16	3	16	5	6	1	0	70 2/	9
MOUNTAIN:																						
Arizona	91	96	70	100	82	90	45	95	64	74	18	86	37	45	3	19	9	11	0	0	70	8
Colorado	88	90	59	-	73	76	35	-	46	48	14	-	18	19	3	-	-	-	-	-	70	5
Idaho	83	89	70	75	66	74	46	50	51	61	26	25	24	31	6	25	10	14	2	-	70 2/	7
Montana	78	90	52	86	62	77	29	57	43	56	15	43	27	37	6	0	14	19	3	0	3/	5
Nevada	91	95	82	100	76	85	54	87	55	67	30	87	35	45	13	50	17	23	4	0	3/	5
Utah	90	92	84	-	70	73	50	-	45	51	16	-	23	25	2	-	-	-	-	-	70	2
PACIFIC:																						
California	86	-	-	-	62	-	-	-	32	-	-	-	11	-	-	-	2	-	-	-	4/	7
Oregon	83	94	62	-	58	81	12	-	37	35	1	-	17	25	0	-	5	7	0	-	70	2
Washington	88	92	64	86	65	72	26	39	44	50	6	12	13	16	1	0	-	-	-	-	70	5
AVERAGE Above Stated	87	92	71	86	69	77	38	69	44	53	13	47	22	27	3	12	7	10	1	0		
Alaska 5/	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hawaii	-	-	-	-	30	30	-	-	-	-	-	-	3	3	-	-	-	-	-	-	65	1

1/ All stations have the same speed limits unless otherwise noted.
2/ No more than two stations have different speed limits.
3/ Reasonable and prudent.
4/ Speed limit varies by station with 70 m.p.h. maximum.
5/ Alaska has no Interstate mileage, therefore no entries are included.
- Indicates data not available.

TABLE 3.--AVERAGE SPEEDS OF VEHICLES AND PERCENTAGES OF VEHICLES EXCEEDING VARIOUS SPEEDS BY TYPE OF HIGHWAY IN 1970.

No. of States	Type of highway	Average speed m.p.h.				Percent over 35 m.p.h.				Percent over 40 m.p.h.				Percent over 45 m.p.h.				Percent over 50 m.p.h.				Percent over 55 m.p.h.				Percent over 60 m.p.h.				Percent over 65 m.p.h.				Percent over 70 m.p.h.				Percent over 75 m.p.h.			
		All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus	All	P.C.	Tk.	Bus
36	Main rural 1/ 2/	59.2	60.6	54.7	55.8	99	99	99	99	97	98	96	97	93	94	88	87	83	86	73	80	68	73	51	68	47	54	24	51	27	33	8	30	12	16	2	5	4	5	1	0
36	Rural Interstate completed 1/ 2/	63.8	65.6	58.1	63.0	100	100	100	99	100	100	99	99	99	99	96	98	96	99	89	93	87	92	71	86	69	77	38	69	44	53	13	47	22	27	3	12	7	10	1	0
9	Rural Interstate traveled-way 1/ 2/ 3/	58.2	59.2	54.8	60.3	99	99	99	100	98	98	96	100	94	96	69	100	83	86	72	93	65	71	50	71	40	45	25	50	21	25	9	28	9	11	2	9	2	3	1	0
36	Rural primary 1/ 2/	56.7	57.9	53.1	56.9	99	99	98	98	96	97	94	96	93	91	84	84	77	80	66	75	58	63	42	61	36	41	18	45	17	21	6	23	7	8	1	5	3	4	1	0
18	Urban Interstate completed 1/ 2/	55.6	56.6	52.4	53.8	100	100	98	100	97	97	93	94	89	91	91	87	74	77	60	61	55	58	38	45	31	34	18	28	12	14	4	8	3	4	1	2	1	1	0	0
4	Urban Interstate traveled-way 3/	44.3	44.8	42.2	44.5	83	84	81	86	72	74	68	78	55	57	46	55	33	37	20	31	14	16	5	7	5	5	2	0	1	1	0	0	0	0	0	0	0	0	0	0
4	Suburban Interstate completed	60.8	62.2	56.3	63.5	100	100	100	100	100	100	99	100	97	98	93	98	91	94	83	95	76	81	59	87	57	64	31	78	30	36	9	50	12	16	1	19	3	4	0	0
	Freeways and toll roads:																																								
	Connecticut parkways	60.1	60.1	-	-	100	100	-	-	100	100	-	-	100	100	-	-	100	100	-	-	84	84	-	-	44	44	-	-	0	0	-	-	0	0	-	-	0	0	-	-
	Connecticut Turnpike	61.5	62.3	59.2	60.6	100	100	100	100	100	100	100	100	100	100	100	100	98	99	94	100	91	92	85	96	56	61	40	54	18	23	3	0	0	0	0	0	0	0	0	0
	Maine Turnpike	66.1	-	-	-	100	-	-	-	100	-	-	-	100	-	-	-	100	-	-	-	96	-	-	-	88	-	-	-	58	-	-	-	26	-	-	-	-	-	-	-
	Michigan freeways	63.4	65.0	56.9	65.9	100	100	100	100	100	100	99	100	99	99	95	100	94	96	86	100	83	88	62	88	64	73	29	83	41	50	5	62	20	24	0	21	5	7	0	0
	Nevada freeways	65.8	68.4	60.2	68.8	100	100	100	100	100	100	99	100	99	100	97	100	96	99	91	100	91	95	82	100	76	85	54	87	55	67	30	87	35	45	13	50	17	23	4	0
	New Hampshire Turnpike	63.6	63.8	58.8	-	100	100	100	-	100	100	100	-	100	100	100	-	98	98	98	-	94	95	83	-	77	79	30	-	57	59	12	-	18	18	2	-	7	7	0	-
	New Jersey Gardenstate Parkway	60.4	60.4	-	-	100	100	-	-	100	100	-	-	99	99	-	-	97	97	-	-	81	81	-	-	67	67	-	-	18	18	-	-	6	6	-	-	1	1	-	-
	New York Thruway	63.7	64.2	60.8	66.2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	98	100	96	97	89	100	85	89	70	100	49	52	26	77	12	14	3	11	1	1	0	0
	Oklahoma turnpikes	65.5	66.7	56.2	-	100	100	99	-	100	100	97	-	96	100	90	-	97	99	80	-	92	96	62	-	84	90	42	-	62	68	15	-	31	35	4	-	5	6	0	-
	Oregon freeways	62.8	66.0	56.3	-	100	100	100	-	100	100	100	-	100	100	100	-	96	99	91	-	83	93	63	-	58	82	11	-	38	56	1	-	16	23	0	-	4	6	0	-
	Pennsylvania freeways	53.3	55.0	50.4	52.8	100	100	99	100	98	99	95	99	[illegible]	[illegible]	80	80	67	76	51	56	38	49	19	43	13	19	4	16	2	3	0	1	0	0	0	0	0	0	0	0
	Rhode Island freeways (rural)	58.5	59.6	54.3	56.3	100	100	100	100	100	100	97	100	98	99	94	100	94	97	82	86	75	79	53	71	49	54	22	29	15	17	3	0	4	5	0	0	1	1	0	0
	Rhode Island freeways (urban)	49.3	50.0	45.2	47.0	99	100	95	95	97	99	87	95	[illegible]	53	53	73	54	58	33	32	15	17	6	4	6	7	2	0	1	1	1	0	0	0	0	0	0	0	0	0
	Texas-Ft. Worth-Dallas Turnpike	62.1	63.7	57.9	59.4	100	100	100	100	99	100	96	100	[illegible]	99	93	100	91	96	75	74	84	89	59	68	57	66	35	47	40	47	21	37	7	9	3	5	2	3	1	0
	Texas-Stemmons Freeway	56.2	56.5	55.4	50.3	100	100	100	100	99	99	99	100	[illegible]	98	97	89	82	87	79	39	65	69	59	29	14	17	9	0	3	4	[illegible]	0	0	0	0	0	0	0	0	0
23	Rural secondary 1/ 2/	51.6	52.6	48.7	49.7	95	96	89	94	88	90	81	79	76	78	66	64	57	60	44	31	37	39	25	26	18	20	9	18	8	9	3	13	3	3	1	3	2	2	0	0
19	Urban primary	45.4	46.1	43.0	42.8	79	79	69	70	70	70	58	55	53	53	38	38	36	36	22	17	21	20	9	10	10	9	3	6	3	3	1	2	1	1	0	0	0	0	0	0
6	Urban secondary	35.7	35.8	34.6	31.6	49	49	41	26	27	27	20	22	15	16	8	22	8	9	5	11	5	5	2	0	2	2	1	0	1	1	1	0	0	0	0	0	0	0	0	0
7	Suburban primary	51.7	52.6	48.1	47.1	99	99	96	92	92	95	83	87	75	80	62	58	56	60	47	40	35	38	22	15	19	21	8	8	7	9	2	2	2	3	0	2	0	0	0	0

1/ Percentages for 70 m.p.h. are based on 34 States for main rural roads, for rural primary, and for rural Interstate completed; 5 States for rural Interstate traveled-way. 17 States for urban Interstate completed 22 States for rural secondary.
2/ Percentages for 75 m.p.h. are based on 25 States for main rural roads, and for rural Interstate completed, 18 States for rural primary; 6 States for rural Interstate traveled-way; 12 States for urban Interstate completed; 10 States for rural secondary.
3/ Rural Interstate traveled-way includes roads, and urban Interstate traveled-way includes streets that are adequate for present traffic but have not been upgraded to full Interstate design standards, and those older sections of existing roads and streets that are presently serving the Interstate traffic in Interstate corridors.
- Indicates data not available.

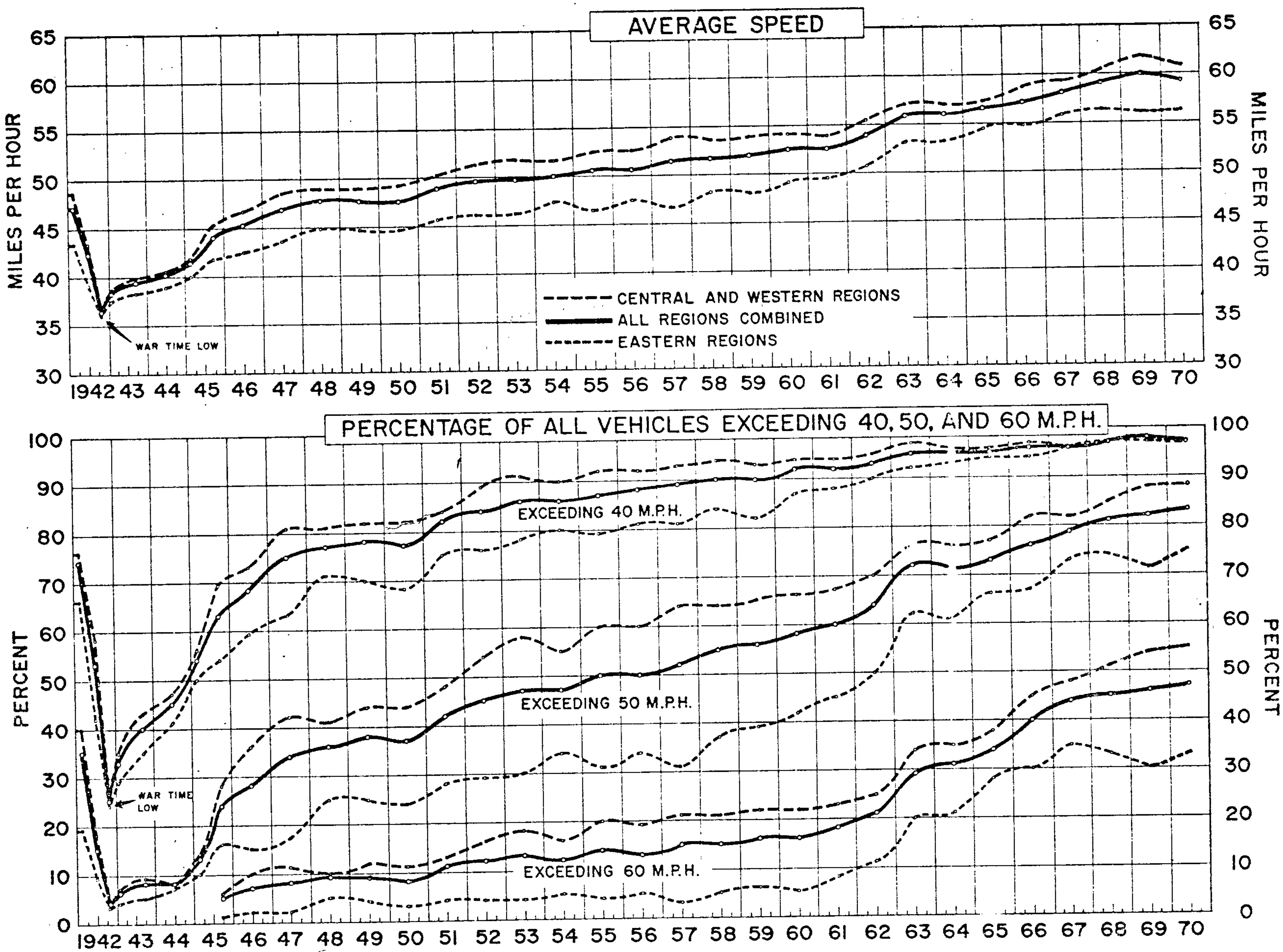


FIGURE 1–SPEED TRENDS ON MAIN RURAL HIGHWAYS BY REGIONS

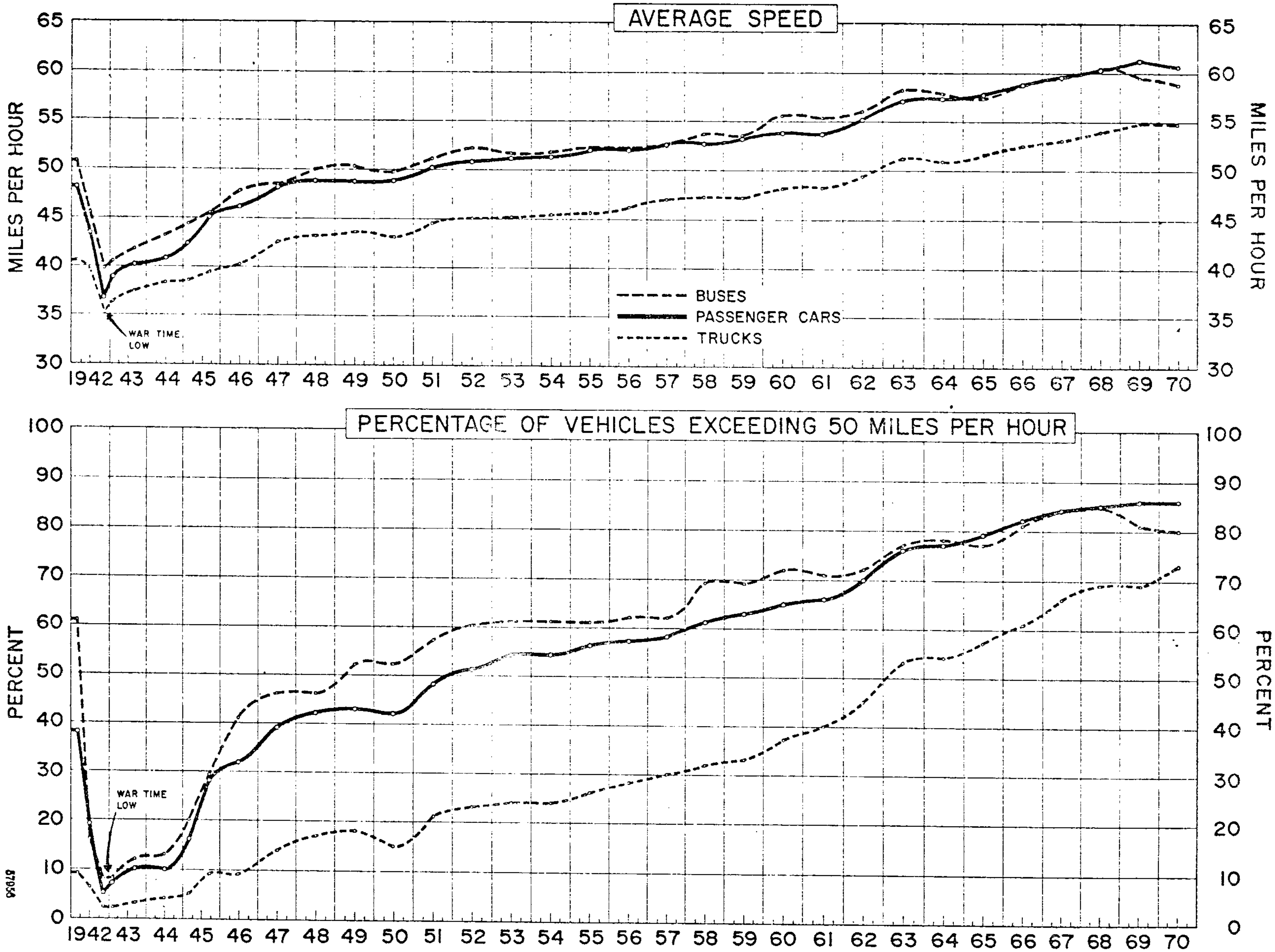


FIGURE 2–SPEED TRENDS ON MAIN RURAL HIGHWAYS BY VEHICLE TYPE

Table 1
Average annual passenger car travel in thousands of miles classified by vehicle class and population group of residence of the operator: 1969

Population group of residence	Vehicle class				Number of Samples
	Light American	Medium American	Heavy American	Foreign Autos	
Unincorporated	12.4	12.7	11.1	13.2	1684
Incorporated					
Less than 5000	10.7	11.5	13.8	12.1	514
5000 - 24999	11.3	12.0	14.4	11.6	909
25000 - 49999	9.7	13.0	10.4	13.4	370
50000 - 99999	10.3	11.7	8.9	11.7	400
100000- 999999	10.9	11.4	12.4	12.5	785
1000000 & over	8.5	11.5	8.0	13.5	250
Total incorp.	10.6	11.8	11.7	12.4	3228
TOTAL	11.2	12.1	11.6	12.6	4912
No. of samples	2891	1482	160	379	4912

Source: Nationwide Personal Transportation Study
U.S. Bureau of Census for FHWA

May 15, 1972

Fuel Economy in Passenger Car
4000 lb.

Facts

34 percent of vehicle miles are to and from work.

9.4 miles is average length of trip.

Computations

This one-way trip would take about $9.4 \times .05 = 0.47$ gallon for warmed-up engine under ideal driving conditions - level straight road free-flowing traffic at $30^{\pm}$ mph.

(A) If this trip is with cold engine fuel consumption is increased about 20 percent above that for warmed-up engine or to 0.56 gallon.

(B) If trip involves driving over arterial streets, no parking, but with 2 stops per mile, multiply fuel consumption by 1.46. Cold engine $0.56 \times 1.46 = 0.82$ gallon.

(C) Supposing one mile of trip is in CBD on 6-lane street with parking, 10 stops in mile, 200 vehicles per hour one-way, and assuming cold engine for return trip home, that one mile would require 3.6 times as much fuel as ideal conditions or $3.6 \times 0.05 = 0.18$ gallon. Remaining 8.4 mi. @ $0.056 \times 1.46 = 0.69$ gallon total for trip home 0.87 gallon or average mileage of 10.8 miles/gallon.

Fuel Savings

$$\text{(A) over (B)} = \frac{(.82 - .56)100}{.82} = \frac{.26}{.82} \times 100 = 31.8\%$$

$$\text{(A) over (C)} = \frac{(.87 - .56)100}{.87} = \frac{.31}{.87} \times 100 = 35.6\%$$

May 15, 1972

Discussion: Principal Approaches to Conserve Fuel (5 May '72)

Item 2 Reduce top speed from 80 to 60 mph.

Question: Assuming reduction in speed could be attained, which is doubtful, what percentage of passenger cars travel at 80+ mph and what saving in total fuel consumption could be expected?

Answer: About 6 percent of cars on main rural highways do travel in excess of 75 mph when road is level and straight (so-called desired speed). The total vehicle miles of travel on main rural roads in 1970 was 310×10^9. Arbitrarily assuming that only half of the main rural roads are level and straight one might estimate that $\frac{1}{2} \times 310 \times 10^9 \times 0.06 = 9 \times 10^9$ miles are being traveled at speeds in excess of 75 mph.

The gasoline consumption for a typical 4000 lb. passenger car is about 0.075 gal. per mile at 75 mph and 0.058 gal. per mile at 60 mph. The saving of 0.015 gal. per mile times 9×10^9 miles equals 135×10^6 gals. total saving from reduction in speed.

This potential saving of 135 million gallons of gasoline amounts to 135/66,000 = 0.2 percent of the total fuel (66,000 million gallons) consumption by passenger cars. Even if the saving were doubled as it might be by assuming that passenger cars can and do travel at high speeds on grades the saving in fuel would still be around 0.4-0.5 percent.

My personal opinion is that, in relation to other alternatives, effort devoted to curtailing top speeds solely to conserve fuel is not worth pursuing.

16 May 1972

CONVERT EXISTING VEHICLES TO LIQUEFIED GAS FUELS

1. CONCEPT

The reduction in energy (BTU) requirements to power the motor vehicle by utilizing natural or liquefied gases as an alternate fuel to gasoline.

2. OBJECTIVE

The systematic substitution, in fleet owned vehicles, of gasoline as a prime internal combustion engine fuel with a gaseous or lower energy, cleaner burning fuel -- natural gas, in a liquid (LNG) or compressed (CNG) state, or liquid petroleum gas (LPG).

3. PRESENT STATUS

A. Maturity - Natural gas has been used as a fuel for the I. C. E. in the gas transmission industry for several decades. Additionally, LPG has been used to power industrial equipment for many years. The expansion of this technology has, during recent years, grown in its applicability to the motor vehicle, especially the use of natural gas. It has been reported that approximately 300, 000 units are now operating on LPG; about 10 percent are motor vehicles. There are now over 3,000 CNG vehicles and 500 LNG vehicles operating in the United States.

B. Support Level - The support of this concept has been furnished by many diversified interested organizations for various reasons. Two of the main reasons are economic and environmental. For example, natural gas has been used as a vehicle fuel in Italy and France for many years for economic reasons because of the high price of gasoline. Japan has the largest fleet of taxicabs in the world that is operated on LPG. This is for economic and ecological reasons.

In the United States, the use of these fuels has drawn expanding interests among a great diversity of governmental and private parties, and the interest is divided equally between the ecologists and economists.

C. Contributors - The gaseous fueled vehicle concept has had at its disposal a wealth of information shared by the many organizations either producing or utilizing the equipment or products now available. This exchange of data and information has resulted in changing technology and equipment improvement.

4. OUTLINE OF PROBLEMS

A. Fuel Supply

B. Hardware Availability

C. Initial Capital Expenditure

D. Advanced Technological Research

5. RECOMMENDED ACTION

A. Funding Levels - Initial capital outlay for the equipment in its current state will be the single most costly expenditure. As the state of the art advances and quantative purchase power is exerted, equipment cost should curtail.

Funding for existing projects has been shared by governmental, industrial and private organizations. For example, recently the National Transportation Center announced a pilot project to equip city transit buses, diesel powered, with liquid natural gas fuel systems. Costs for the project are being shared by the Center, the Federal Government, and the four cities which will operate these buses.

We recommend this practice continue, but be expanded to include the gas industry and the automotive manufacturers.

B. Timetable - The technology is available now. The refinement of existing systems can be accomplished within a short period of time.

We recommend that industry involvement be accelerated so that their expertise and resouces can contribute to short term implementation.

C. R & D Teams - Various Federal and private organizations are now testing, evaluating and refining systems utilizing gaseous fuels. Additional R & D, for example, by the automotive manufacturers and the gas industry, could provide valuable assistance in optimazation of equipment and systems.

We recommend a committee be formed to oversee the entire gaseous fuel concept. This committee should consist of representatives of governmental and industrial organizations that can contribute to this concept. At its disposal should be the needed cooperation of Federal, automotive and gas industries, including their R & D functions.

6. RANK

7. ESTIMATED EFFORT

Although basic research in this concept is well beyond the thinking stage, additional research commitments covering advanced technology, resources and material availability must be investigated.

A budget of approximately $2 million should suffice in expanding the current state of the art. This amount, controlled by the aforementioned committee and made available from Federal and industrial sources, would cover, in the order listed, the following schedule:

A. Accumulation of existing data and information on the current state of the art.

B. Study the impact of the concept on the natural resources.

C. Advancement of technology on existing equipment.

D. Advancement of the concept to encompass the manufacturing of vehicles and their power plants to the optimum operation on gaseous or liquid gases.

E. To study the impact and feasibility of expanding the concept to include all motor vehicles.

8. IMPACT ON RESOURCES

Current trends indicate that fuel economies for gasoline powered vehicles will not improve in the near future, but will deteriorate as vehicle emission standards become more stringent. The addition of exhaust gas recirculating and catalitic converter equipment to achieve 1975-76 exhaust emission standards will increase fuel consumption. The clean burning qualities of natural gas can off-set this potential increase in fuel energy drain.

In a report written of our first experience in natural gas fueled vehicles, it was indicated that natural gas vehicles obtained a better miles per equivalent gallon than gasoline powered vehicles. The gasoline vehicles operated at 9.15 miles per gallon and vehicles operating on natural gas obtained 9.30 miles per equivalent gallon (based on 100 cubic feet per gallon).

It should be noted that these statistics were obtained from 24 vehicles; 12 operating on gasoline and 12 on natural gas. Additionally, the vehicles operated mainly at low speeds and for high idle periods.

A zealous gaseous fueled vehicle effort will have a real impact on natural and liquid gas supplies. However, the trade-off achieved could reflect a savings in energy.

9. ENVIRONMENTAL AND ECOLOGICAL IMPACT

Attached is a brief history of GSA's Dual-Fuel Program. Included are data which relate to the reduction in vehicle exhaust contaminants achievable by using natural gas in lieu of gasoline.

10. CONCLUSIONS AND RECOMMENDATIONS

16 May 1972

COMMENTS ON

SMALL VERSUS STANDARD-SIZE PASSENGER VEHICLES

Reference: Analysis of Energy Consumption of Highway Vehicles Related to Transportation Service, 1969.

1. Passenger vehicles use 70% of the fuel consumed by highway vehicles:

   Passenger Cars: 62,325 (10^6) gallons
   Total: 88,122 (10^6) gallons

2. Passenger density is the same for small and standard-size passenger vehicles.

   Both: 2.2 passengers/vehicle.

3. Small passenger vehicles are:

   (a) Less comfortable

   (b) Less safe, particularly in encounters with heavier vehicles.

   (c) But perform acceptably (not necessarily optimally) in existing highway situations.

4. Present alternate engine approaches to meet emission standards are sized to meet standard passenger vehicle specifications:

   See "Vehicle Design Goals - Six Passenger Automobile," EPA Advanced Automotive Power Systems Program, Revision B - May 28, 1971.

5. Small passenger vehicles have about 70% improved fuel economy over standard-size vehicles.

   Small vehicle: 22 mpg
   Standard vehicle: 13.14 mpg

6. Recommended Action:

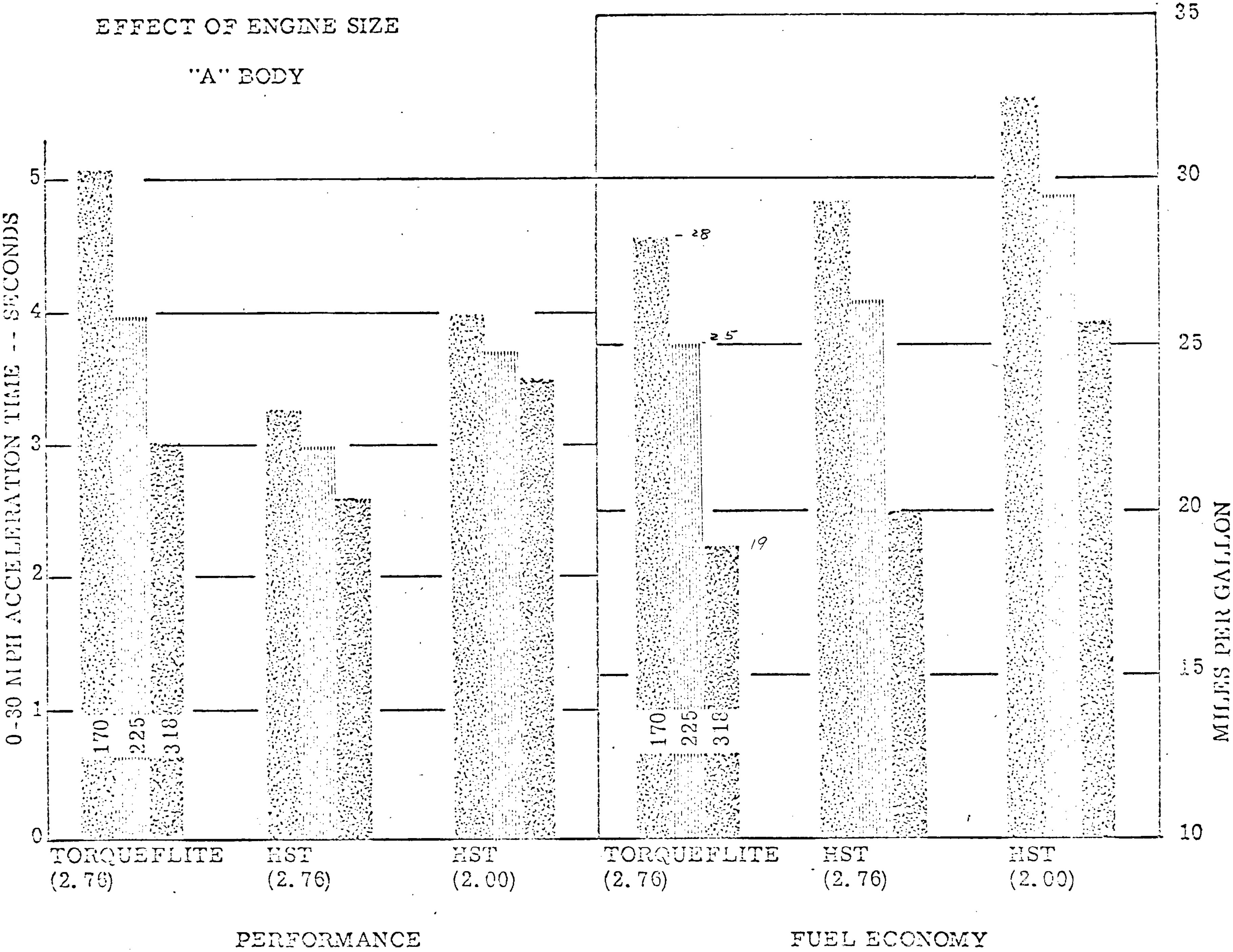
   Since this concept (i.e., small passenger vehicle in 2000 lbs GVW range) has highest potential for transportation energy resource conservation, without adversely impacting passenger density, consider feasibility of:

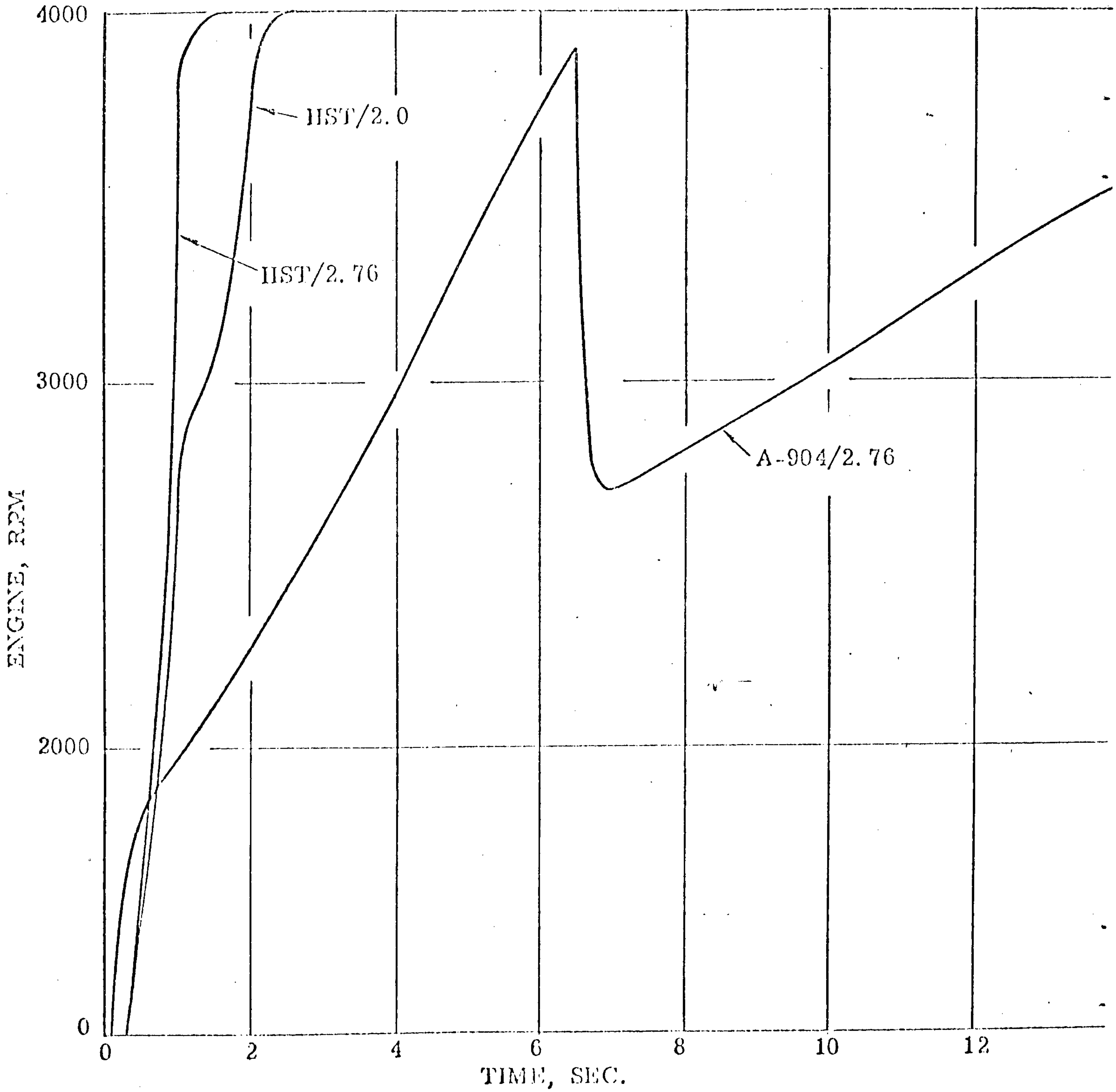
   (a) Writing a specification for this size vehicle.

   (b) Studying impact of primary utilization of this size vehicle within 10-year time period.

EFFECT OF ENGINE SIZE

"A" BODY

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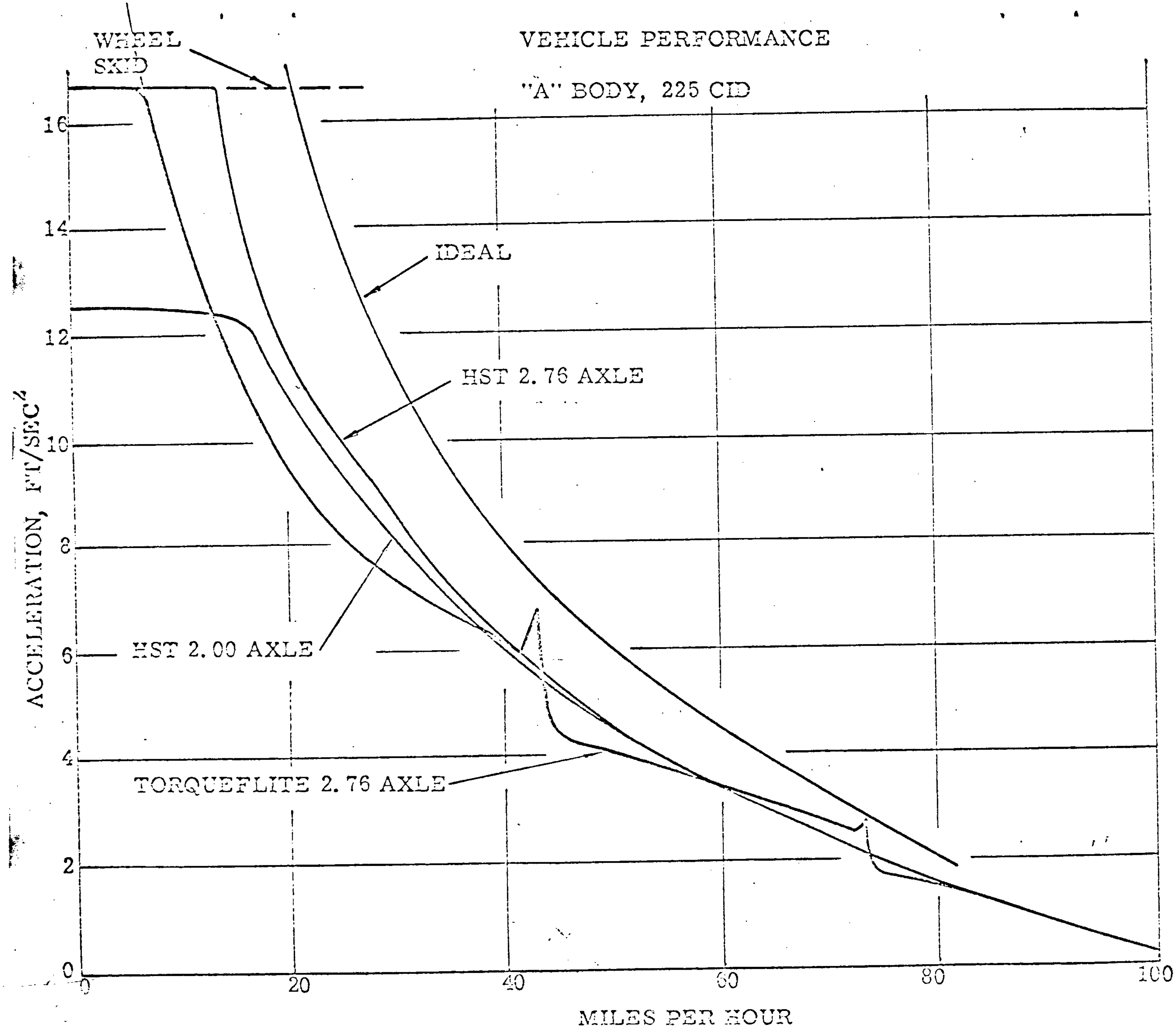
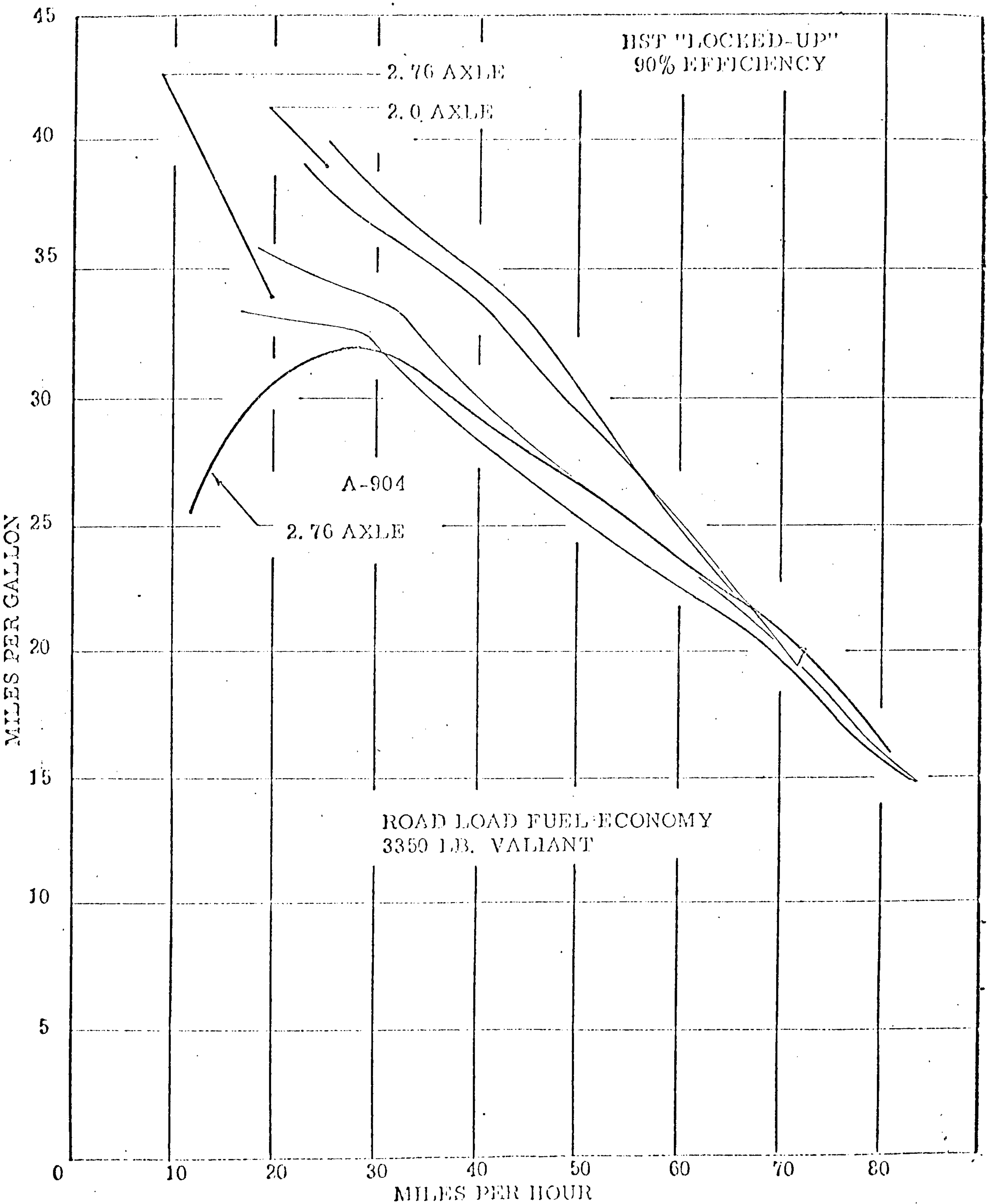
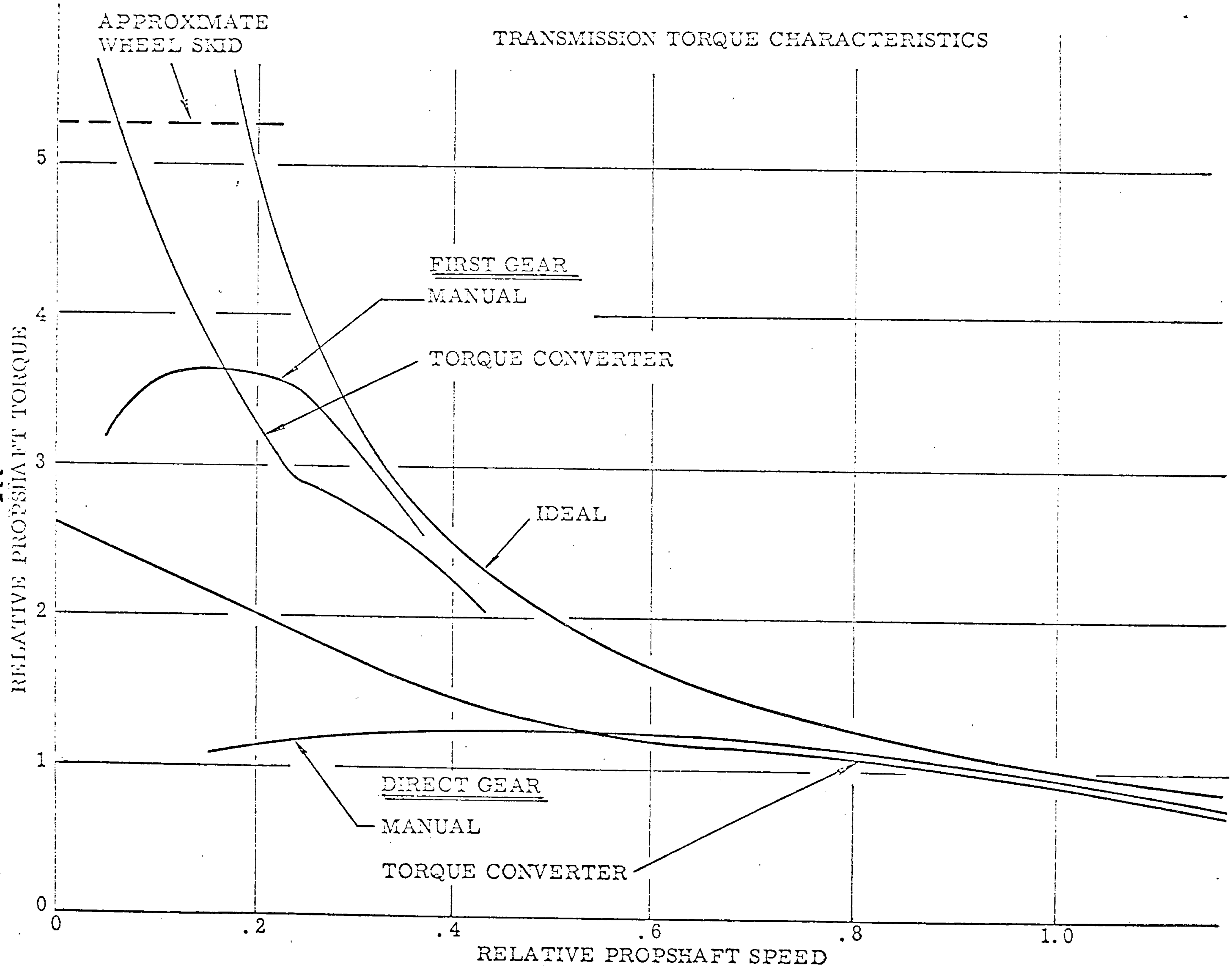
2000
0
ENGINE, RPM
0
2
4
6
8
10
12
TIME, SEC.
HST/2.0
HST/2.76
A-904/2.76


VEHICLE PERFORMANCE
"A" BODY, 225 CID
WHEEL SKID
IDEAL
HST 2.76 AXLE
HST 2.00 AXLE
TORQUEFLITE 2.76 AXLE
ACCELERATION, FT/SEC²
MILES PER HOUR
0
2
4
6
8
10
12
14
16
20
40
60
80
100

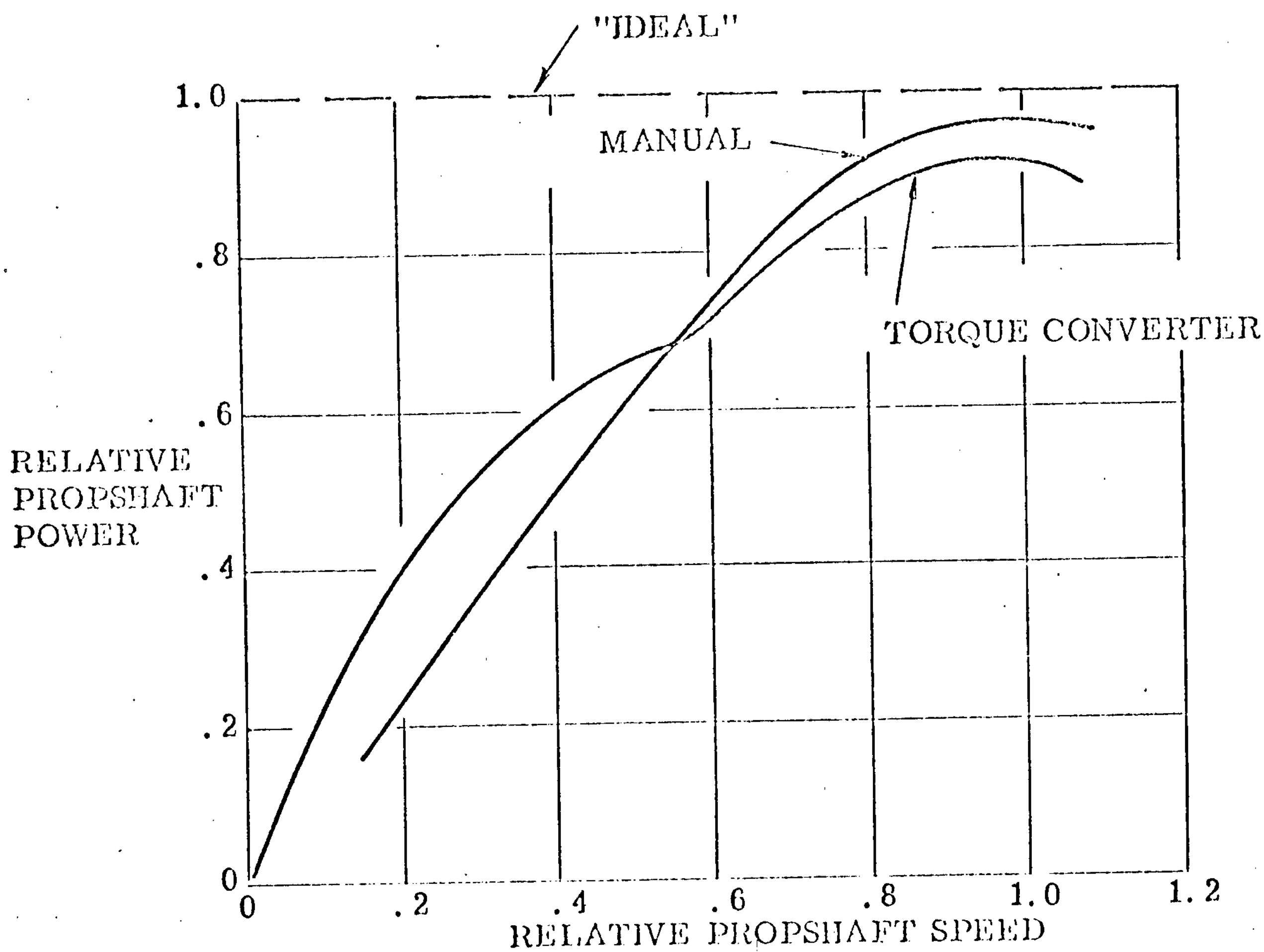

BST "LOCKED-UP"
90% EFFICIENCY
2.76 AXLE
2.0 AXLE
A-904
2.76 AXLE
ROAD LOAD FUEL ECONOMY
3350 LB. VALIANT
MILES PER GALLON
MILES PER HOUR
0
5
10
15
20
25
30
35
40
45
10
20
30
40
50
60
70
80

HYDROSTATIC vs. TORQUEFLITE

POTENTIAL ADVANTAGES	RELATED DEFICIENCIES
STEPLESS RATIOS	EFFICIENCY VARIATION LIMITED REVERSE TORQUE (size) HYDRAULIC NOISE WEIGHT
LOW AXLE RATIO 1. IMPROVED ECONOMY 2. REDUCED ENGINE NOISE (lower speed)	AXLE NOISE ? FAN NOISE ?
IMPROVED PERFORMANCE	ENGINE NOISE AT BREAKAWAY
VARIABLE BRAKING	REQUIRES CONTROL
PUSH START	
NO CREEP	


TRANSMISSION TORQUE CHARACTERISTICS
APPROXMATE
WHEEL SKID
FIRST GEAR
MANUAL
TORQUE CONVERTER
IDEAL
DIRECT GEAR
MANUAL
TORQUE CONVERTER
RELATIVE PROPSHAFT TORQUE
RELATIVE PROPSHAFT SPEED
0
1
2
3
4
5
.2
.4
.6
.8
1.0

TRANSMISSION
POWER
CHARACTERISTICS



CHOSEN PRESENTATION

Concept Name: Energy storage amplification through increased inlet air density.

1. Concept Outline: Use stored energy to increase the mixture density supplied to a small displacement engine to "amplify" the energy and thereby reduce the amount that needs to be stored.

   a. Charge density modifiers
      1. Super (turbo) charger
      2. Inlet air chiller

   b. Energy storage
      1. Compressed air
      2. Fly wheel
      3. Hydraulic accumulator
      4. Electrical

2. Allow the use of a small engine in order to increase load factor under normal operation and thereby reduce fuel consumption.

3. Present Status:

   a. Past work - GM researched a system with compressed air energy storage that used an ejector type fluid dynamic compressor in the induction tract (in the air cleaner inlet tube). The system gave V-8 performance from a 6 cylinder engine with essentially 6 cylinder engine economy. It did not go into production because of complexity and concern with short-term availability of the ejector compressor.

   b. Preferred system - A turbocharger can give considerable boost but has poor transient response. Compressed air acting on a special section of the turbo wheel could be used to very quickly accelerate the supercharger. Alternately, a rapidly rotating flywheel could be clutched into the compressor wheel, or the hydraulic output from the power steering pump used. (Note: that this later suggestion is not technically a stored energy approach).

4. Outline of Problems: The most basic technical problem is the poor match of octane requirement for normal and peak power operation. Normally peak power operation required a reduced compression ratio which compromises efficiency at normal power output. Possibly a dual fuel (second fuel, high octane gasoline or alcohol) or an octane improving concentrate approach could be taken.

5. Recommended Action: Develop a practical solution to the octane problem and determine the practical compression ratio. At this compression ratio quantify the economy advantage. If warranted, proceed with component development and paper studies to determine the optimum system. Build and test the "optimum" system.

6. Rank:

7. Estimated Effort:

8. Impact on Resources: Fuel saving of 10 to 20 percent.

9. Environmental and Ecological Impact: Unknown

10. Conclusions and Recommendations:

RADIAL PLY TIRES

VS

BIAS PLY TIRES

(COMMERCIAL HI-WAY TREAD)

US AIR FORCE TESTS

	BIAS PLY	RADIAL PLY	IMPROVEMENT FACTOR
NUMBER OF TIRES	133	45	
TOTAL TIRE MILEAGE	2,053,756	1,816,626	
MILES PER TIRE	15,600	40,200	158%
VEHICLE MILES/GAL FUEL	5.5	6.1	10.9%

RADIAL PLY TIRES

VS

BIAS PLY TIRES

DRAWBAR PULL

SAND	30% INCREASE
WET ICE	50% INCREASE
PACKED SNOW	20% INCREASE
MUD	SAME
HARD SURFACE	SAME

RADIAL PLY TIRES

VS

BIAS PLY TIRES

PERFORMANCE PARAMETER	SERVICE PARAMETER	IMPROVEMENT FACTOR
STOPPING ABILITY	• DRY HARD CLAY	10%
	• WET HARD CLAY	30%
GRADEABILITY	• SANDY SLOPE	5%
ROLL RESISTANCE	• SAND	45%
	• MUD	15%
	• SNOW	15%
	• ICE	15%
	• HARD CLAY	20%
TREAD LIFE	• VARIABLE	70%
FUEL CONSUMPTION	• VARIABLE	5%

RADIAL PLY TIRES

VS

BIAS PLY TIRES

COMMERCIAL TRUCKING EXPERIENCE

COMPANY	FUEL ECONOMY	INCREASE TREAD LIFE	REDUCED TIRE MAINTENANCE
NEPTUNE MOVING, NEW YORK, NEW YORK	28.0%	67.0%	"MUCH LESS"
MOTOR CONVOY, INC., ATLANTA, GEORGIA	17.3%	--	--
MITCHEL BROS., PORTLAND, OREGON	11.2%	"MARKED"	--
W. S. HATCH CO. WOODS CROSS, UTAH	18.0%	67.0%	"DRASTIC REDUCTION"
CONSOLIDATED EDISON, NEW YORK, NEW YORK	--	100.0%	--
DEVINE AND SON, SACRAMENTO, CALIFORNIA	14.0%	--	"SIGNIFICANT"
HUSTON TRUCK LINE, FRIEND, NEBRASKA	13.0%	--	--
COMMERCIAL CARRIER CORP, AUBURNDALE, FLORIDA	14.0%	"MUCH GREATER"	"REDUCED"
SCHAEFER BREWERY NEW YORK, NEW YORK	--	100.0%	"TREMENDOUS REDUCTION"
ARROW MOTOR TRANSIT, CHICAGO, ILLINOIS	10.0%	--	--

RADIAL PLY TIRES

VS

BIAS PLY TIRES

(MILITARY TREAD DESIGN)

ADVANTAGES

- INCREASED TREAD LIFE 70 TO 100%
- VEHICLE FUEL ECONOMY 5 TO 7%
- PUNCTURE RESISTANCE
- INCREASED VEHICLE MOBILITY OFF ROAD

DISADVANTAGES

- INITIAL INVESTMENT COST
- LIMITED PRODUCTION BASE
- LOGISTIC PROBLEMS IN CHANGE OVER